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米粒外觀與胴割粒率間相關性之探討[1]

趙 政 男[2]

摘要 為瞭解水稻胴割粒率在各類型品種間之差異，及進一步探討米粒外觀與胴割粒率間之相關性，以提供良質米品種之選育及實施稻米品質分級產銷時之參考。利用引自日本及本省育成之稉稻、國內外秈稻及大粒型稻等各類型水稻品種，共計35個為供試材料。在栽培管理與收穫調製齊一之條件下，調查品種間胴割粒率之差異性。初步結果顯示，各類型水稻品種之胴割粒率，以大粒型品種之42.89%為最高，次為引自日本及本省育成之稉稻品種平均為29.21%與26.57%。而以長粒型秈稻品種為最低僅1.79%。顯示胴割粒率除在不同類型水稻間有顯著差異外，在同類型不同品種間亦有極顯著之差異存在。導致水稻胴割粒率在各類型品種間發生顯著差異之主要原因，似與粒形的長短大小與心腹白有無等米粒外觀性狀有關。粒形愈肥大，且心腹白面積愈大者，其胴割粒之發生率亦愈高。

由於國民所得增加，生活水準普遍提高，加上近年來本省稻米生產過剩，國人對於稻米之需求，已不再祇求充飢果腹而已，轉而殷切的力求質佳味美的良質米。於是為了迎合消費者的嗜好，及緩和本省稻米的過分滯銷，稻米之品質已逐漸受到消費者及有關糧政當局的重視，因而年來有稻米品質分級產銷之倡議。且有關本省稻米品質分級標準之訂定工作，目前已在臺中區農業改良場積極進行中[(1)]。

影響稻米品質的優劣，主要取決於碾米性質（milling quality）、米粒外貌（grain appearance）與烹調食用品質（cooking and eating quality）等[(1,5,16,20)]。其中最為消費者所重視，而直接取決米質好壞的主要因素，實為烹調及食用品質之實際品評結果。但食味（適口性）之好壞，因消費者嗜好之不同，很難確立一定標準，品評結果亦因人而異[(1,5)]。因而若能從米粒外觀上尋求與食味極具顯著相關的性狀，則將帶給稻米品質分級上不少方便，且在育種上亦可做為篩選良質稻米時之依據。

米粒外觀係一品種特性，主要有粒型的長短大小（size）、透明度（translucency）及心腹白(chalkiness)等[(2,19)]，而該等因子不但影響碾米品質[(3,18)]，且對烹調食用品質亦有極顯著影響[(2,5,6)]。著者[(7)]於1981到1982年間在米粒外貌與烹調食用品質之相關性試驗中，發現碎米粒做成之米飯，其適口性（粘彈性、軟硬度）顯然較完整米粒者為差。故降低碾米時之碎米率為提昇稻米食用品質之直接且有效的方法。

胴割粒是造成碎米率增加，導致碾米率與完整米率降低之主要原因[(8,14)]，而碎米率與完整米率之高低是決定稻米商品價值與食用品質之主要因素之一。因此如能降低碎米率來提高完整米率，則無形中可增加白米之商品量，且可提昇白米的商品價值與食用品質。故如何減少碎米率，以提高完整米率便成為整個水稻良質米生產栽培過程中不可忽視的一環。

1.臺灣省農業試驗所 研究報告第 1506 號。本計劃承行政院農業委員會補助〔78農建—7.1—糧—11(16)〕，謹致謝意。
2.本所嘉義分所農藝系助理研究員。臺灣省 嘉義市。

胴割粒的形成要因很多[8,13,15,17]而胴割粒率之高低，品種間存在著極大的差異[8,15]。本試驗之主要目的乃在進一步探討米粒外觀與胴割粒間之相關性，以提供良質米品種之選育及實施稻米品質分級產銷時之參考。茲將著者於民國七十七年第一、二期作在嘉義農業試驗分所之初步觀察結果報告如下。

材料與方法

本試驗依試驗目的分由兩部份進行，試驗材料與實施方法分別列述如下：

一、粒形與胴割粒間之相關性：

本試驗之供試材料計有本省改良育成之臺農67號等10個稉稻品種，引進之 Arborio 等 4 個大粒型水稻品種，臺中在來一號等10個國內外秈型稻品種，笹錦等11個日本稉稻品種，總計有35個供試品種（如表一）。田間種植採隨機排列，重複 3 次，每品種每重複插植 3 行，每行10株，行株距25×20公分，單本植。生育期間之栽培管理均按一般慣行法實施，適期收穫，收穫後利用日曬法乾燥，直至稻穀含水率爲13—14%時，做爲測試材料。測試前每品種每重複各取 100粒充實粒以測定粒長、粒寬、粒厚等。胴割粒之測定是將供試材料先以 Satake 碾米機依一般方法脫穀碾成糙米（重複碾兩次），而後每品種各取充分成熟的糙米500粒供檢定。所用胴割粒檢定器爲日本製「胴割ーチエツカ—DC 50型」。胴割粒之鑑定標準是只要在米粒上呈現有斷裂紋者即視爲胴割粒，而不論其斷裂紋的長短及斷裂紋數的多寡。

二、心腹白與胴割粒間之相關性：

本試驗利用本省良質米契作生產計劃內所推薦的四個良質米品種，臺農68號、臺農70號、臺南 9號、臺中 189號，而以臺農67號爲對照等共計五個爲供試品種。田間試驗設計及栽培管理均比照上一試驗實施。稻穀成熟收穫後，利用日曬法乾燥至稻穀含水率爲13—14%時做爲測試材料。測試時每品種每重複各取500公克稻穀，先以Satake 碾米機脫穀碾成糙米（重複碾兩次），棄除碎米粒，而後依完整粒上心腹白的有無與大小，比照1978年 Khush et al[19]之分類標準劃分成下列四等級：（1）完全無心腹白。（2）心腹白僅有針頭狀痕跡或已開始擴展，但其擴展度佔全粒米之10%以下。（3）心腹白已有顯著擴展，而其擴展度佔全粒米之10～20%。（4）心腹白之擴展度佔全粒米之20%以上。而後利用胴割粒檢視器調查各心腹白等級上胴割粒率之差異情形。

表一、供 試 水 稻 品 種

Table 1. Rice cultivar used.

Origin	Variety name
Japonica varieties (Improved in Taiwan)	Tainung 67, Tainung 68, Tainung 69, Tainung 70, Tainung 72, Tainan 7, Tainan 9, Taichung 189, Taichung 190, Kaohsiung 142.
Japanese varieties	Kiyonishiki, Satohomare, Hatsuhosi, Akihomare, Sasanishiki, Fuzeminori, Yamabiko, Gohyakumangoku, Kusafue, Kokonoe, Ooseto,
Indica varieties	Tainung sen 12, Tainung sen 14, Tainung sen 18, Tainung sen 19, Tainung sen 20, Taichung native 1, IR 54, IR 56, IR 60, IR 62,
Large grain varieties	BG 11, LM 79, Arborio, Lomello,

結果與討論

一、各類型水稻品種間胴割粒率之差異性：

本試驗調查各類型水稻品種計35個，其胴割粒率之測定結果示如表二，由表中可看出稉稻品種之

表2.供試品種胴割粒率之變異性

Table 2. variability of cracked kernels of rice varieties.

Japonica variety				Indica variety				Large grain variety	
Improved in Taiwan	Mean±S. D.	Japanese	Mean±S. D.	Long grain	Mean±S. D.	Medium or short grain	Mean±S. D.	Variety	Mean±S. D
Tainung 67	24.67±3.59	Kiyonishiki	25,67±5.82	Tainung sen 12	2.33±1,37	Taichung native 1	6.67±2,98	BG 11	67.33±3.19
Tainung 63	44.67±4.57	Hatsuhoshi	29.67±6.57	Tainung sen 14	1.00±0.94			Arborio	8.00±2.58
Tainung 69	31.67±5.34	Akihomare	47.33±9.28	Tainung sen 18	0.67±0.94			Lomello	53.33±4.98
Tainung 70	16.67±2.75	Sasanishiki	27.00±7.63	Tainung sen 19	1.00±1.00			LM 129	42.83±8.49
Tainung 72	18.67±5.62	Satohomare	47.33±7.54	Tainung sen 20	1,83±1,46				
Tainan 7	26.67±4.71	Fuzeminori	42.60±4.10	IR 54	2,67±2.21				
Tainan 9	27.00±5.13	Yamabiko	21,30±3.77	IR 56	1.67±1.00				
Taichung 189	28.33±2.13	Gohyakuman-goku	46.33±3.54	IR 60	1,33±1,54				
Taichung 190	26.00±3.27	Kusafue	6.67±4.10	IR 62	5.00±1.91				
Kaohsiung 142	21.33±2.49	Ooseto	23.67±5.34						
		Kokonoe	3.67±1.79						
Mean±S. D.	26.57±8.41		29.21±14.78		1.79±1.40		6.67±0		42.89±25.32
Range	16.67~44.67		3.67~47.33		0.67~5.00		—		8.00~67.33

胴割粒率，其變異範圍爲3.67%—47.33%，平均爲27.89%。其中引自日本之粳稻品種，其胴割粒之變異範圍爲 3.67%—47.33%，平均爲29.21%。國內改良育成之粳稻品種胴割粒率之變異範圍爲16.67%—44.67%，平均爲26.57%。秈稻品種胴割粒率之變異範圍爲0.67%—6.67%，平均爲2.33%，其中長粒型秈稻品種之變異範圍爲 0.67%—5.0%，平均爲1.79%。而短粒型秈稻品種，供試品種中僅臺中在來一號，其平均胴割粒率爲6.67%。至於大粒型水稻品種胴割率之變異範圍爲8.0%—67.33%，平均爲42.89%。就各類型水稻品種而言，胴割粒率以大粒型稻之42.89%爲最高，其次爲引自日本之粳稻品種及國內改良育成之粳稻品種，其胴割粒率之平均值爲26.57%—29.21%，而以長粒型秈稻品種之胴割粒率最低僅1.79%。就各品種於重複間取樣之變異情形示如表二，由表中可看出秈稻品種之變異性較粳稻與大粒型稻爲小。由以上結果，除顯示胴割粒率在水稻不同類型間有顯著之差異外，在同類型不同品種間亦有極顯著之差異存在。類此結果，著者[8]於1988年已有相同報告提出。

在相同之栽培環境與收穫調製齊一之條件下，導致胴割粒率在各類稻型間與同類型不同品種間之差異，推論其原因除了受調製環境因子之影響外，可能與品種本身穀粒之軟硬度及穀粒特性（如粒形之長短大小與心腹白之有無等）有某種關係存在。1973年日人長戶氏等[14]曾指出米粒之軟硬度不但類型間有所差異，即使同類型不同品種間亦有顯著差異存在，因而有軟硬質種之區別。而米粒之軟硬度除了與米粒理化學上的組織成分不一有關外，又與米粒上白堊質（chalkiness）之有無大小有密切關係[11,14,18]。具心腹白的米粒其質地常較完全無心腹白者爲軟，碾白時之碎米率又高於完全無心腹白者[1,4,16,20]。由是推論米粒上心腹白的有無及大小與胴割粒率間可能有某種關係存在。而大粒型或寬粒型水稻品種之心腹白率又高於細長粒型[9,10,12]，以是粒形之長短大小與心腹白之有無等米粒外觀性狀，可能與胴割粒率高低之間亦存有密切關係。爲了提供良質米品種之選育及實施稻米品質分級產銷時之參考，米粒外觀與胴割粒率間之相關性，便有待進一步的探討。

二、心腹白與胴割粒間之相關性：

爲調查心腹白之有無大小與胴割粒率間之相關性，以本省四個良質米推薦品種，另加上栽培面積最廣的臺農67號爲對照計五品種。經調查結果示如表三，由表中可看出不同心腹白等級間，其胴割粒率之差異，五個品種之平均結果，依心腹白的有無大小依序分別爲Ⅰ期作爲68.40%—60.91%—59.33%—55.33%。Ⅱ期作爲36.60%—32.42%—28.53%—23.13%。顯示各心腹白等級間胴割粒率之差異，以1級完全無心腹白者爲最低，其次爲心腹白等級屬2級者，平均較1級完全無心腹白者高出4.0～5.4%，3級又較1級高出5.58—9.29%，而以心腹白等級屬4級者，亦即心腹白面積超過米粒之20%以上者，其胴割粒率爲最高，平均較1級完全無心腹白者高出達13.07～13.47%。兩期作之表現結果相當一致，即胴割粒之發生率以完全無心腹白者爲最低，而後隨著心腹白面積之增加與擴大，胴割粒之發生率亦隨之提高。由是推論從米粒外觀上篩選無心腹白粒品種無形中可降低胴割粒之發生率，且在碾白調製上亦可降低碎米率而提高完整米率。

目前本省良質米之篩選過程中，無心腹白或低心腹白率品種爲篩選良質米品種時，米粒外觀上之必備條件，而此等性狀爲篩選過程中最簡單容易，且不需假手繁雜儀器，人人均可用肉眼加以判別鑑定的重要指標性狀。預期朝此方向繼續予以選優汰劣後，不久的將來將可使本省水稻品種的加工品質獲得改善，除可降低碎米率來提高完整米率外，無形中亦可提昇本省稻米之商品價値與食用品質。

三、粒形與胴割粒率間之相關性：

粒形與胴割粒率間之相關性，經分析結果示如表四，由表中可看出日本引進品種其粒長、粒寬、粒厚等穀粒性狀與胴割粒率間之相關係數分別爲0.3779、0.4897、−0.0350。本省改良育成之粳稻品種則分別爲0.3909（粒長）、−0.2679（粒寬）、−0.1303（粒厚）。由上可知粳稻品種之粒形與胴割粒率間之相關係數均未達顯著水準，且部份相關係數均相當小，顯示粳稻品種胴割粒之發生率受品種粒形之影響較小。至於秈稻品種之穀粒性狀與胴割粒率間之相關係數則分別爲−0.8086**（粒長）、0.7282*（粒寬）、0.3024（粒厚），顯示秈稻品種胴割粒之發生率可分別受到粒長、粒寬等顯著影

表三、心腹白大小對胴割粒率之影響：

Table 3. Effect of chalkiness area on the rate of cracked kernel.

Crop season	Grade of Chalkiness*	Tainung 67	Tainung68	Tainung70	Tainan 9	Taichung 189	Averge	Rate (%)
1988, 1st	1	68.67a	58.33a	44.00a	30.00a	75.67a	55.33	100.00
	2	74.33ab	58.98a	52.34b	34.67a	76.33a	59.33	104.00
	3	75.33b	62.33a	58.33b	32.30a	76.24a	60.91	105.58
	4	79.31b	72.37b	69.16c	41.18b	80.00a	68.40	113.07
1988, 2nd	1	30.40a	28.00a	11.60a	22.00a	26.40a	23.13	100.00
	2	29.20a	49.20b	17.60a	21.20a	27.20a	28.53	105.40
	3	34.40ab	52.40b	29.60b	23.20a	27.60a	32.42	109.29
	4	40.10b	53.30b	39.30c	24.50a	29.60a	36.60	113.47

*: 1. Without any chalkiness or completely translucent.
2. Chalkiness area less than 10%.
3. Chalkiness area from 10% to 20%.
4. Chalkiness area more than 20%.

**: Means followed by the same letter in a variety are not significantly different at 5% level by Duncan's multiple range test.

響，其中與粒長的相關性呈極顯著之負相關。而大粒形品種之穀粒性狀與胴割粒率間之相關係數則分別為−0.7939（粒長）、0.0448（粒寬）、0.5501（粒厚），雖均未達顯著水準，但與粒長呈負相關，而與粒寬、粒厚呈正相關。綜合以上結果，雖然各類稻型間粒形與胴割粒率間所呈現之相關係數有正負相反之差異存在，但經綜合分析結果，其相關係數則分別為粒長（−0.3562）、粒寬（0.7011**）、粒厚（0.6256**）。顯示粒寬、粒厚與胴割粒率間均呈極顯著之正相關。由是推論米粒愈肥大者，胴割粒之發生率亦愈高。因米粒愈肥大者，白堊質之出現率亦愈高[4,10]。1985年劉氏[9]亦曾指出大粒形品種穀粒之充實程度較差，造成之心腹白率亦較多。而由表三結果，胴割粒之發生率隨著心腹白面積的增加與擴大，胴割粒之發生率亦隨之提高。此現象適足以說明各類型水稻間之胴割粒率何以以大粒型稻為最高，而以長粒型秈稻為最低之主要原因。因本省改良育成之長粒型秈稻，其粒寬、粒

表四、粒形與胴割粒率間之相關性

Table 4. Correlation coefficient of grain shape and cracked kernel.

	Length	Width	Thickness
Japanese varieties	0.3779	0.4897	−0.0350
Japonica varieties (improved in Taiwan)	0.3909	−0.2679	−0.1303
Indica varieties	−0.8066**	0.7282*	0.3024
Large grain varieties	−0.7939	0.0448	0.5501
Total	−0.3562	0.7011**	0.6256**

*and**: significant at 5% and 1% levels, respectively.

厚顯然的小於大粒型稻與粳稻，而其心腹白率又顯然的低於大粒型稻與粳稻[9]。

綜合以上結果，雖然影響胴割粒的外在環境因素很多，並非人力所能全部控制，但在同一栽培環境與收穫調製齊一的條件下，却可顯示出胴割粒率在水稻品種間有極大之差異存在。導致胴割粒率在水稻品種間發生顯著差異之主要原因，似與米粒理化學上之組織成分不一有關，而粒形的長短大小與心腹白的有無等米粒外觀性狀，亦爲其影響要素之一。故爲提昇本省良質稻米之育種效率，以加速良質米品種之選育，有關良質米品種的篩選過程中，是必要將粒形與心腹白等米粒外觀性狀列爲重要的指標性狀。

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Variation of Cracked Kernel and Its Correlation to Grain Appearance in Rice

Chao cheng-nan

Summary

The variation of cracked kernel rate (CKR) in thirty-five rice varieties and its relation to grain appearance were studied for further grading of rice quality and variety selection. Great diversity of CKR was identified in evaluated rice varieties. The average CKR was recorded as 42.89% in varieties with large grain and followed by two grops of Japonica type (26.56% and 29.21%, respectively). The CKR of long-grain Indica type was only 1.79%. The results appear that large differences of CKR existed among varieties either between two types or within type. Further studies indicated that the coefficients of correlation between grain shape and CKR were −0.3562 (kernel length), 0.7011** (kernel width) and 0.6256** (kernel thickness), respectively. It implies that greater grain size and chalkiness area are related to higher CKR and they may be indexes for selection ol high grain quality rice variety.

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單雜交玉米臺農1號及其父、母本自交系氮素同化與利用性狀對兩種氮肥用量的反應[1]

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摘要：本試驗以臺農1號及其父、母本自交系爲材料，採用氮素用量 60 與 180kg/ha 處理，探討基因型與氮肥用量對乾物質與氮素累積及分配的影響，著重吐絲前與吐絲後的比較，並經由氮素利用效率組成因子分析，解釋產量表現的差異。施用重氮肥明顯增加成熟期植株乾物質與子粒產量，收穫指數有提升趨勢，自交系與雜交種之反應相同。雜交品種於吐絲後生成之乾物量佔總乾物量60%以上，並爲子粒產量之1.25倍以上，氮肥用量的作用不明顯，顯示具有充份的同化能力因應子粒充實需要，其表現亦頗穩定。臺農1號父本植株吐絲後累積乾物量爲子粒重之1.7倍，顯示產量極端受限於積儲能力，母本之表現則與雜交種相近。低氮肥條件下臺農1號葉片氮素濃度低於父、母本自交系，推測不足以支持高光合作用速率，又父本營養及生殖器官氮素濃度極高，與其積儲強度較弱有關，但雜交種子粒碳氮比值顯著較父、母本爲高，顯示三個基因型子粒累積碳素與氮素的相互配合速率應有不同。臺農1號植株每公頃累積氮素量最高可達 230 kg以上，氮素收穫指數爲0.67-0.71，後者不受氮肥用量影響；臺農1號母本植株之氮素收穫指數僅爲 0.47-0.52，但氮素分配於苞葉與穗軸比率顯著超過父本及雜交種植株，顯示父、母本在碳素及氮素利用方面的差異。臺農1號吐絲後累積氮素量爲總含量之60%以上，並與子粒含氮量相近，亦即具有旺盛的氮素同化能力；父、母本自交系吐絲後累積氮素量爲總含量之 26-51%，且父本之累積量僅爲子粒氮含量之41-73%，氮素同化能力可能限制產量表現。玉米氮素利用效率以雜交種最高，主要的影響因子爲氮素吸收效率及子粒內單位氮量之對應乾物生成量，氮素吸收效率因氮肥用量增多而降低，可供今後品種選育之參考。

氮素爲作物生長必需的營養要素，與產量表現有密切的關係；玉米屬 C_4 型植物，具有較高的氮素利用效率，依據 Ku *et al.*[15] 與 Schmitt and Edwards[23] 的報告，與 C_3 型或部份其它 C_4 型植物比較，玉米葉片可利用較少的蛋白質進行與乾物質生產有直接關係之光合反應，但仍維持極高的乾物質生產能力。唯不同基因型玉米的氮素利用效率有所差異[11,13]，而且在經濟栽培時如欲獲得高產，仍應多施氮肥，顯示玉米爲需肥頗重之作物；在氮肥需要量及將所吸收之氮素表現於產量的效率方面，品種間的差別亦大[9]，在實際栽培時，均爲值得注意的問題。

部份玉米品種吐絲期時已累積最終含氮量之80% 以上，子粒充實對再轉移性氮素的依賴度極高

1.臺灣省農業試驗所　研究報告第1507號。本試驗承行政院農業委員會補助（計畫78農建-7.1-糧-24-4），謹致謝意。本文爲第一作者碩士論文之一部份。

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[23]，有些品種吐絲期植株含氮量則僅為成熟期總含量之半，子粒充實所需氮素主要由根部吸收供應[9]，兩類型品種的生理特性有異，產量潛能亦以後者為優。玉米子粒累積氮素與碳水化合物之間也有密切的平行關係，因此植株供應氮素與子粒累積氮素的能力是決定產量的重要因子[33]；就同一品種而言，果穗累積氮素量多者，其子粒產量亦高。依據 Moll *et al.*[18] 的研究，氮素利用效率（N use efficiency）可再被區分為氮素吸收效率（N uptake efficiency）與氮素應用效率（N utilization efficiency），並可各予區分為細部組成因子，用以判別玉米品種對氮素的利用能力，以及針對氮素的產量效率（yield efficiency）表現。Kamprath *et al.*[13] 與 Moll *et al.*[18] 並據以提出改良品種氮素利用效率的建議。

氮素利用效率受品種與栽培條件的影響，本省飼料玉米的栽培方法與制度雖已建立，但對新育成品種在不同栽培條件下吸收氮素與應用氮素於子粒生產的內在生理性狀仍然缺少充份的瞭解。本項研究利用新育成之推廣品種臺農1號為材料，施以兩種氮肥用量處理，經由分析植株各器官累積氮素的量與速率，計算氮素利用效率及其組成因子，同時比較父、母本自交系之表現，藉以對玉米產量生理有進一步的瞭解。

材料與方法

本試驗於1988年秋作在本所農場進行，於9月17日播種，播種時每穴播兩粒種子，出土後間拔留一株；播種後施用萌前殺草劑 Primextra(3.5 L a.i./ha)防治雜草。植株生長至齊膝期時中耕培土，生育期間多次施用農藥防治病蟲害，適時灌溉，並按慣行法行田間管理。秋作試驗進行前採取土壤樣品，委請本所農業化學系分析土壤肥力，其土質屬坋質壤土（SiL），pH 值 5.75，有機質 2.13%，CEC 為 7.8 meq/100g，銨態氮 13.3 ppm，硝酸態氮 16.8 ppm，有效性磷（Bray 1）16 ppm，有效性鉀（Mehlich）106 ppm。

氮肥試驗係以臺農1號單雜交品種及其父本自交系 TA3651—377 與母本 TA2808—176 為材料，栽培之行株距為 75×20 cm，合每公頃 66,666 株，氮素（N)用量分兩個等級，即 60 與 180 kg/ha，磷、鉀肥用量為 P_2O_5：K_2O＝90：100 kg/ha，氮肥（硫酸）銨之 40%與半量之磷肥（過磷酸鈣）及鉀肥（氯化鉀）各於播種時以基肥及播種後 25 日以追肥施用，其餘 20%氮肥於播種後 45日用為第二次追肥。試驗小區均為 8 行區，行長 6m，面積 36m²，重複 3 次，採用逢機完全區集設計。

各試區均於吐絲期、吐絲後 36 與 56 日及成熟期取樣，共為四次。每次自每小區逢機選取 6 株為樣品，自土面收穫地上部，區分為葉片、莖稈、雄穗、苞葉與穗部，於送風乾燥箱中乾燥，再將穗部分為穗軸及子粒，秤量乾物重後以 Wiley mill 經 40 目（mesh）篩磨粉，貯藏於附內蓋之 PE 塑膠瓶中供化學分析之用。

乾物重測定係將樣品於送風乾燥箱中以100°C 烘乾 2 hr，繼以 80°C 烘乾至完全乾燥（約48—72 hr）後秤量之。全氮依 semi-micro Kjeldahl 法分析。又利用植株乾重與氮素濃度乘積計算氮素含量後，依據 Moll *et al.*[19] 之下列公式估算氮素利用效率；在考慮氮素供應量時，僅注重施用之氮素肥料量，而未慮及土壤本身之氮素供應能力，為採用下列公式的一項先決條件。

$$Kw/Fs = Nm/Fs \cdot Kw/Nm$$

$$Kw/Nm = Kw/Kn \cdot Kn/Nm$$

$$Kn/Nm = Na/Nm \cdot Kn/Na$$

$$\therefore Kw/Fs = Nm/Fs \cdot Kw/Kn \cdot Na/Nm \cdot Kn/Na$$

其中 Kw 為子粒產量，Fs 為施用之氮素肥料量，Nm 為成熟期植株地上部總含氮量，Kn為子粒內氮素含量，Na 為吐絲至成熟期間植株所累積之氮量，所使用之單位統一為 g/plant 或 kg/ha。Kw/Fs 即為氮素利用效率，Nm/Fs 稱為氮素吸收效率，Kw/Nm 為氮素應用效率，Kn/Nm為氮收穫指數，Na/Nm 表示子粒充實期間植株累積氮量與成熟期總含氮量之比值，Kn/Na 表示子粒含

氮量與子粒充實期間植株累積氮量之比值，Kw/Kn 爲子粒重與子粒含氮量比值。

測定與分析結果均經變方分析，並以鄧肯氏多變域法(Duncan's New Multiple Range Test)比較處理間之差異性。

結果與討論

氮肥用量對玉米乾物質生產與分配的影響

以臺農 1 號品種及其父、母本爲材料，施以兩種氮肥用量 (60 與 180 kg N/ha) 處理，測定乾物重的結果列於表 1。吐絲期臺農 1 號葉片、莖稈與全株總乾重均隨氮肥用量增加而提高，但苞葉與穗軸之差異不顯著。成熟期則除葉片外，氮肥用量對其他器官與全株總乾重均有正的效應存在；低肥處理時臺農 1 號植株總乾重與子粒產量分別爲 12.35 與 5.59 t/ha，重肥處理爲 18.65與 9.63 t/ha，以後者較高。玉米之乾物質生產表現對氮肥的反應雖因品種而異 ， 但一般皆隨施用量的增加而提高 [7]。由於重肥處理顯著增加臺農 1 號之葉片重量(表 1)與葉面積(資料未列出)，有利於對光能之利用，應與全株乾物產量增加有密切關係 [20,35]。Remison and Fajemisin [22] 測定氮素對玉米雜交與合成品種乾物質生產能力的影響，發現前者在 75 kg/ha 及後者在 150 kg/ha 時能有最高之乾物產量；Anderson *et al.* [4] 除證明氮肥用量對玉米乾物質生產的重要性外，同時建議多穗型品種在重氮肥條

Table 1. Influence of fertilization on the dry weight of different plant organs of Tainung 1 corn hybrid and its paternal inbred TA3651—377 and matternal inbred TA2808—176 at silking and maturity

Variety	N Rate	Leaf	Stalk	Husk	Cob	Kernel		Whole Plant	
	kg/ha	g/plant				g/plant	t/ha	g/plant	t/ha
					Silking				
Tainung 1	60	21.7 b*	40.4 b	3.3 c	1.5 b	—	—	66.9 bc	4.46 bc
	180	27.0 a	52.4 a	5.6 bc	2.8 b	—	—	87.8 a	5.85 a
TA3651—377	60	15.2 c	28.9 bc	3.1 c	1.4 b	—	—	48.6 d	3.24 d
	180	17.3 c	35.7 bc	5.2 bc	2.5 b	—	—	60.8 cd	4.05 cd
TA2808—176	60	16.4 c	24.0 c	6.3 b	2.6 b	—	—	49.3 d	3.29 d
	180	25.2 a	40.0 b	11.4 a	6.4 a	—	—	82.9 a	5.53 ab
					Maturity				
Tainung 1	60	29.7 a	45.4 b	11.5 b	14.6 c	83.9 b	5.59 b	185.2 b	12.35 b
	180	33.6 a	62.9 a	17.4 a	21.4 b	144.5 a	9.63 a	279.8 a	88.65 a
TA3651—377	60	13.3 c	31.5 cd	8.1 c	14.2 c	26.9 d	1.73 d	92.9 c	16.19 c
	180	20.4 bc	48.7 b	12.0 b	25.8 a	59.6 c	3.97 c	196.4 b	11.09 b
TA2808—176	60	14.1 c	24.7 d	12.0 b	8.4 d	45.1 c	3.01 c	104.3 c	6.95 c
	180	22.1 b	41.3 bc	18.7 a	14.9 c	80.1 b	5.34 b	177.0 b	11.80 b

*Means with the same letter within a column of an individual developmental stage are not signi-ficantly different at 5% leAel by Duncan's New Multiple Range Test.

件下能有最高之反應。在國內 Lian [17] 探討氮肥用量對臺農 351 號品種之影響，發現春作施肥量自70增加至 210 kg N/ha 及秋作自 100 增加至 300 kg N/ha 時，作用並不明顯，春作與秋作的乾物產量分別為 10 及 15 t/ha 左右；Wang *et al.* [34] 認定臺農 351 號為需肥量頗高的品種，建議在栽培時應注意土壤肥力與氮素用量的適度配合，臺農 1 號品種也有相同的表現。

臺農 1 號父本（TA3651—377）吐絲期各器官與全株乾重對氮肥用量均無反應，但成熟期除葉片外，於處理間的差異均達顯著水準；母本自交系（TA2808—176）的表現較不相同，無論吐絲期或成熟期，各器官與全株乾重均隨氮肥用量提升而增加，與臺農 1 號的表現趨勢較為相近（表 1）。父本自交系於低肥處理之子粒產量為 1.73 t/ha，重肥時為 3.97 t/ha，僅為臺農 1 號之三分之一左右，母本自交系於低、重肥處理之子粒產量分別為 3.01 與 5.34 t/ha，雖低於臺農 1 號，但仍顯著高於父本自交系（表 1）。Balko and Russell [5] 研究氮肥對10個玉米自交系的影響，報告與不施氮肥比較，施用 60 kg N/ha時有顯著的增產效果，但再增加氮素用量至 120 或 180 kg/ha 的效應則多不顯著，與本試驗氮素用量 180 kg/ha 仍可增加乾物及子粒產量的結果有異，推測為基因型不同所致，此外，環境因子也可能具有影響，Balko and Russell [5] 即曾指出基因型與地區及氮素用量均有交感作用存在。

當氮肥用量由 60 增加至 180 kg N/ha 時，臺農 1 號及其父、母本植株吐絲期葉片乾重佔全株乾重比值均有下降趨勢，但以父本 TA3651—377 的表現最明顯；苞葉與穗軸比率亦有隨之增高的傾向，唯僅於部份基因型內達到顯著水準。於基因型間比較，母本 TA2808—176 莖稈所佔比率最低，苞葉及穗軸所佔比率則最高。氮肥用量對成熟期植株乾物質分配的影響亦不明顯，僅有之例外為臺農 1 號之葉片與子粒及父本之莖稈。在收穫指數方面，臺農 1 號之低肥與重肥處理分別為 0.453 與 0.516，以後者較高，母本之指數分別為 0.432與 0.453，低肥情況下與雜交種較為接近，但父本最低，低肥與重肥處理僅及 0.279 與 0.358（資料未列出）。

氮肥用量對玉米吐絲後乾物質生產能力的影響

玉米植株於吐絲後（子粒充實期間）累積乾物量（Da）與吐絲期與成熟期乾重（分別為 Ds 與 Dm）及子粒產量(Kw)的比值列於表 2；氮肥施用量為 60 及 180kg N/ha 時，臺農 1 號 Da/Ds 比值分別為 1.77 與 2.19，父本 TA3651—377為 0.91 與 1.74，母本 TA2808—176 為 1.12 與 1.14，同一氮肥處理以臺農 1 號較高，除母本外，並均隨氮肥用量增加而升高。Da 與成熟期全株乾重比值(Dm)代表玉米植株吐絲後乾物生產量的比重，三個基因型的比值較為接近，但低肥時仍以臺農 1 號最高（0.64），父、母本分別為 0.48 與 0.53，兩者之間差異不顯著；重肥處理可提升父本植株 Da/Dm 值，但對母本及臺農 1 號無影響。Da 與子粒乾物重的比值可做為依源能力的一種表示，臺農 1

Table 2. Ratio of whole-plant dry matter accumulated during kernel-filling (Da) to kernel weight (Kw) and whole plant dry weights at silking (Ds) and maturity (Dm) for corn plants subjected to two levels of N fertilization

Genotype	N Supplied (kg/ha)	Da/Ds	Da/Dm	Da/Kw
Tainung 1	60	1.77 b*	0.64 a	1.41 b
	180	2.19 a	0.69 a	1.33 b
TA3651—377	60	0.91 d	0.48 b	1.71 a
	180	1.74 b	0.64 a	1.77 a
TA2808—176	60	1.12 c	0.53 b	1.22 c
	180	1.14 c	0.53 b	1.18 c

*Mean with the same letter within each column are not significantly different at 5% level by Duncan's New Multiple Range Test.

號 Da/Kw 值爲 1.41 與 1.33，父本之 Da/Kw 值高達 1.7，母本較低，爲 1.2 左右，基因型間的差異顯著，但處理間表現則頗爲一致（表 2）。

臺農 1 號品種與父本植株 Da/Ds 比值均有隨施肥量增加而提高的趨向（表 2），顯示具有較高的相對生長速率；在 Da/Dm 比值方面，臺農 1 號均在0.6以上，亦即玉米總乾物產量的60%係於吐絲以後合成，顯示子粒充實過程中的同化作用極爲重要； Genter *et al.*[10] 與王等[1] 均有幾乎完全相同的報告，Tsai[30] 的試驗則發現此一比值最高可達65% ； 但范[3] 於秋作在桃園地區栽培臺農351號品種，指出吐絲後之乾物生成量僅佔最終總乾物量之40% ， 可能爲子粒充實期間不良環境因子（如季節風）的影響所致。有關氮肥用量對 Da/Dm 值的影響方面 ，於同一基因型內多未發現顯示此一性狀的表現頗爲穩定。

至於 Da 與子粒乾重（Kw）的比值，可用以粗估玉米吐絲後現行同化產物與子粒充實需求間的平衡關係；各基因型間表現雖有不同，但處理間的差異則不顯著，顯示在本試驗條件下，氮肥用量並不能改變植株供源與積儲間的關係。各處理所得結果在 1.18-1.77 之間，顯示供源能力超過積儲需求，可爲實際栽培時之參考；其中父本之 Da/Kw 值爲所有處理中之最高者，此一結果固然表示吐絲後有過盛的同化能力，但由於父本之收穫指數僅爲 0.28-0.36（由表 1 計算），Da/Kw 比值因子粒產量低落而升高，因此並不能代表產量的潛能。有關玉米產量受限於供源或積儲，國內外學者的研究結果並無定論 ， 例如改變供源能力可影響子粒產量， 顯示供源能力可能不足[8,12,24,29]，又如降低供源能力並不影響產量，或增大積儲容量可達增產效果 ， 又顯示積儲的可能限制作用[14,19,26,32,35]。本試驗的主要目的雖不在於比較積儲與供源對玉米產量限制的重要性，但由於 Da/Kw 值多在 1.0 以上，臺農 1 號更高達 1.77—2.19（表 2），推測應仍具有充份的供源能力。

氮肥用量對玉米植株氮素累積與分配的影響

氮肥用量對臺農 1 號品種及其父、母本植株各器官氮素濃度的影響列於表 3。一般而言，濃度多隨氮肥用量增加而升高，但絕對值稍低於以往之試驗結果[2]。氮肥用量爲 180 kg N/ha 時臺農 1 號吐絲期葉片氮素濃度爲 2.60%，估算含量約爲 1.3 g N/m^2，與 Sinclair and Horie[29] 所稱，在 0.2—1.2 g N/m^2 的範圍內及光量不爲限制因子的條件下，玉米葉片光合速率呈直線增加的論點比較，應已具有理想的氮素營養；低肥處理葉片氮素濃度爲 1.66%，約合 0.83g N/m^2，含量頗低，可能不足以支持旺盛的光合作用。成熟期葉片氮素濃度明顯下降，莖稈、苞葉與穗軸也有相同的表現，應爲轉移至發育中子粒供充實之需的結果[27,31]，在兩種氮肥處理均有相同表現。

Table 3. Influence of N fertilization on the N concentration (%, db) in different plant organs of Tainung 1 and its paternal inbred TA3651—377 and maternal inbred TA2808—176 at silking and maturity

Variety	N Supplied (kg/ha)	Leaf	Stalk	Husk	Cob	Kernel
			Silking			
Tainung 1	60	1.66 d*	0.44 b	1.10 b	2.60 c	—
	180	2.60 b	10.5 b	1.36 a	2.81 b	—
TA3651—377	60	2.43 b	0.54 b	1.31 a	2.86 b	—
	180	2.91 a	0.79 a	1.32 a	3.00 a	—
TA2808—176	60	1.99 c	0.48 b	0.87 c	1.93 e	—
	180	2.51 b	0.56 b	1.09 b	2.00 d	—

（續）

Variety	N Supplied (kg/ha)	Leaf	Stalk	Husk	Cob	Kernel
		Maturity				
Tainung 1	60	0.99 d	0.28 c	0.27 d	0.65 d	1.16 e
	180	1.44 b	0.39 b	0.36 c	0.84 c	1.39 d
TA3651—377	60	1.48 b	0.41 b	0.46 b	0.86 c	1.68 b
	180	2.24 a	0.52 a	0.62 a	1.15 a	2.08 a
TA2808—176	60	1.19 c	0.33 c	0.30 d	0.88 c	1.60 c
	180	1.36 b	0.42 b	0.45 b	1.06 b	1.72 b

*Means with the same letter within a column of an individual developmental stage are not significantly different at 5% level by Duncan's New Multiple Range Test.

本試驗中最特殊之處爲父本自交系 TA3651—377 各器官之氮素濃度較其餘兩個供試基因型爲高，例如吐絲期之葉片、莖稈（重肥處理）、苞葉(低肥處理）與穗軸部位，父本濃度均顯著超過母本及雜交種(表 3）；而成熟期的差距幅度更大，以臺農 1 號重肥處理之濃度値爲基準，父本葉片、莖稈與穗軸之濃度較其高出 56、33 及 37 %，苞葉更達72%；母本器官濃度雖於部分處理或部位亦超過雜交種，但幅度較小。臺農 1 號成熟子粒氮素濃度在低、重肥處理分別爲 1.16 與 1.39%，母本爲 1.60與 1.72%，較臺農 1 號同處理爲高；低肥區父本子粒氮素濃度 1.68%，重肥區更達 2.08%，極顯著超過臺農 1 號及其母本（表 3）。

上述父本植株氮素濃度特高的現象極可能爲其遺傳特性，但由三個基因型間子粒產量漸高而各器官氮素濃度漸低的事實判斷，也有可能爲積儲强度較弱（子粒產量低）而使氮素於其他器官累積的結果。又由父、母本子粒氮素濃度均顯著超過其雜交種觀之，子粒累積碳素與氮素的相互配合速率應有不同，Tsai *et al.*[32] 即曾由 zein 蛋白質爲玉米子粒氮素積儲（N sink）的觀點討論與產量的關係及基因型間的差異；有關比較自交系與雜交種子粒氮素濃度間關係的研究報告不多，但Tsai[30] 利用高蛋白質與低蛋白質濃度玉米品系行正反交，前者具較低之 C/N 比值，後者則較高，發現 F_1 族羣的 C/N 值與母本相近，而 F_1 植株經自交後，所得單穗子粒未顯示分離現象，但其値介於兩個自交系親本之間；本試驗中以 180 kg N/ha 處理爲例，臺農 1 號及其父、母本之子粒 C/N 比值分別爲28.7、19.2與23.3（資料未列出），顯示雜交種的 C/N 值高於父本及母本，其間的確實關係及意義仍需更多的試驗予以究明。

氮肥用量對玉米植株各器官氮素含量影響的結果列於表 4；三個基因型的氮素含量隨施肥量之增加而提高，但基因型間有很大的差別，在低肥條件下，吐絲期臺農 1 號及其父、母本自交系的全株累積量並無差異，每公頃累積量爲 35.5-41.1 kg/ha，重肥時父本累積量（60.5 kg/ha）則顯著低於母本（73.7 kg/ha）及雜交種（74.9 kg/ha）；成熟期的表現又有不同，各處理均以雜交種爲高（重肥與低肥處理分別爲 233.7 與 134.5 kg/ha），而重肥條件下母本自交系的氮素含量（150.9 kg/ha）又高於父本自交系（118.2 kg/ha）。基因型間子粒氮素含量的變化趨勢與全株的表現大致相同，雜交種臺農 1 號子粒最多可累積 165.3kg/ha 之氮素，爲父、母本之兩倍以上。

在氮肥用量對玉米植株所含氮素於各器官分配比率的影響方面（資料未列出），吐絲期葉片與莖稈所佔比率均在 80%以上，成熟期之比率除母本爲 31-35%外，臺農 1 號及父本植株均在27%以下。除極少數例外，無論在吐絲期或成熟期，氮肥用量於同一基因型內對植株總含氮量分配於各器官的比率並未產生顯著影響。臺農 1 號成熟期子粒含氮量爲植株總含氮量之 66-72%，亦即氮素收穫指數爲

Table 4. Amounts of N accumulated in different plant organs of Tainung 1 and its paternal inbred TA3651—377 and maternal inbred TA2808—176 at silking and maturity as affected by two levels of N fertilization

Variety	N Rate	Leaf	Stalk	Husk	Cob	Kernel		Whole Plant	
	kg/ha	mg/plant				mg/plant	kg/ha	mg/plant	kg/ha
					Silking				
Tainung 1	60	363 c*	177 bc	37 c	40 c	—	—	616 c	41.1 c
	180	706 a	263 a	76 b	79 b	—	—	1,123 a	74.9 a
TA3651—377	60	369 c	155 cd	41 c	41 c	—	—	605 c	40.3 c
	180	503 b	263 a	68 bc	74 bc	—	—	908 b	60.5 b
TA2808—176	60	324 c	113 d	45 bc	50 bc	—	—	532 c	35.5 c
	180	631 a	224 ab	124 a	27 a	—	—	1,105 a	773.7 a
					Maturity				
Tainung 1	60	358 ab	152 b	36 b	129 c	1,343 b	89.5 b	2,017 bc	134.5 bc
	180	459 a	264 a	77 a	226 b	2,480 a	165.3 a	3,506 a	233.7 a
TA3651—377	60	140 c	68 c	32 b	55 d	524 c	34.9 c	818 d	54.5 d
	180	317 b	154 b	67 a	124 c	1,112 b	74.1 b	1,773 c	118.2 c
TA2808—176	60	195 c	126 bc	38 b	121 c	430 c	28.7 c	910 d	60.7 d
	180	458 a	251 a	74 a	297 a	1,183 b	78.9 b	2,264 b	150.9 b

*Means with the same letter within a column of an individual development stage are not significantly different at 5% level by Duncan's New Multiple Rane Test.

0.66—0.72，在氮肥處理間甚爲穩定，雖然父本的子粒產量最低，氮素收穫指數（0.63—0.64）則與雜交種相近，母本的子粒產量雖遠超過父本，指數却僅爲 0.47—0.52。臺農 1 號氮素收穫指數與 Anderson *et al.* [4] 及 Tsai [30] 的結果相似；Tsai [30] 以氮肥處理調節玉米供源能力，指出氮素收穫指數隨施肥量增加而降低，推測其原因，應仍與氮素自營養器官轉移至子粒及子粒積儲對氮素的需求强度有關，換言之，在疏植與重肥條件下，氮素供源能力較高，相對的積儲容量成爲氮素累積的限制因子，與前述乾物質方面的表現有相似之處。

氮肥用量對玉米植株於子粒充實期間累積氮素能力的影響列於表 5，臺農 1 號吐絲後植株所累積氮量（Na）與吐絲期植株含氮量（Ns）之比值爲 2.12—2.27，Na 與成熟期植株總含氮量（Nm）的比值爲 0.68—0.70，Na 與子粒含氮量（Kn）的比值爲 0.96—1.04，均不受施肥處理的影響。父本與母本對氮肥的反應與雜交種臺農 1 號不同，最主要的區別爲 Na/Ns、Na/Nm 及 Na/Kw 比值隨氮肥用量自 60 增至 180kg N/ha 而升高，例如父、母本之 Na/Nm 值分別自 0.26 提高至 0.49 與自 0.42 提高至 0.51（表 5），表示重肥條件下，兩個自交系可於吐絲後累積更多的相對氮素量。

臺農 1 號植株 Na/Nm 比值最高爲 0.70，亦即總含氮量的 70% 係於吐絲後同化，表現極高的氮素同化能力，遠較本研究室其他試驗及其他學者 [2,30] 的結果爲高，其代表性應再確定。一般而言，此一比值多在0.5以下，如與氮素收穫指數爲 0.6—0.7 比較，顯示吐絲後的同化量不足以供應子粒充

實之需，而有氮素再轉移的現象發生[25]。目前已有許多報告指出玉米雜交種間於吐絲後的氮素吸收能力有別[6,21,33]，而且高產的雜交種能於子粒充實期間吸收較多量的氮素，以因應子粒發育的需要，反之，低產品種於吐絲後對氮素的需求程度則較低。Na 與子粒氮素含量（Kn）的比值可用以說明子粒充實期間的氮素供需平衡關係，多數品種的比值均低於 1，亦即營養器官於吐絲前所累積之氮素對子粒充實具有相當的重要性；Schrader[25] 認為再轉移性氮素佔玉米子粒內氮素量之比率最高可達84%，此一數值雖有偏高的可能，但足以說明其重要性。在氮肥試驗中發現臺農 1 號的 Na/Kn 值隨氮肥施用量增加而下降（表 5），其反應與疏植情況下的結果相同[2]，Tsai[30] 也曾有類似的報告。

Table 5. Ratio of N amount accumulated by the whole plant during kernel-filling (Na) to kernel N content (Kn) and N contents ofwhole plant at silking (Ns) and maturity (Nm) for corn plants subjected to two levels of N-fertilization

Genotype	N Supplied (kg/ha)	Na/Ns	Na/Nm	Na/Kn
Taiunng 1	60	2.27 a*	0.70 a	1.04 a
	180	2.12 a	0.68 a	0.96 a
TA3651—377	60	0.35 d	0.26 c	0.41 c
	180	0.95 b	0.49 b	0.7 b
TA2808—176	60	0.71 c	0.42 b	0.88 ab
	180	1.05 b	0.51 b	0.98 a

*Means with the same letter within each column are not significantly different at 5% level by Duncan's New Multiple Range Test.

氮肥用量對玉米氮素利用效率組成因子的影響

表 6 為氮肥用量對玉米氮素利用效率組成因子影響的結果；子粒產量（Kw）與施用氮素肥料量（Fs）之比值即為氮素利用效率，本試驗中 Kw/Fs 皆隨氮肥用量增多而降低，三個基因型的表現一致；成熟期植株總含氮量（Nm）與 Fs 之比值為氮素吸收效率，亦以低肥處理為高，差異並極顯著；雜交種臺農 1 號上述兩項比值均顯著超過父、母本自交系。Kw 為子粒乾物量，Kw/Nm 代表植株所含氮量之相對子粒產量，稱為氮素應用效率，除母本植株以低肥處理為高外，其餘未顯示處理效應。低氮肥處理植株單位氮素含量的相對子粒產量（Kw/Nm）與總乾物產量（Tw/Nm）及子粒產量與子粒含氮量之比值（Kw/Kn）均以母本最高(分別為 49.6、105.0 與 114.6)，臺農 1 號（Kw Nm 與 Kw/Kn）或父本（Tw/Nm）居次。氮素收穫指數（Kn/Nm）以父本及雜交品種較高（0.63—0.71），母本僅為 0.47—0.52；另一項明顯的差異為 Na/Nm，臺農 1 號高達 0.68—0.70，母本較低（0.42—0.51），且氮肥處理間無差異，父本則最低（0.26—0.94），並以重肥處理較高。綜合而言，多項氮素利用效率之組成因子或對氮肥用量不具反應，或以重肥處理為高，而基因型間之差別以低肥處理最為明顯。

依 Kw/Fs 定義之氮素利用效率僅為產量差異的另一種表現方法，並不具特殊意義，唯如細分其組成分，則有助於對植株氮素供需平衡及與子粒產量間關係的瞭解[18]。氮素利用效率可分為氮素吸收效率（Nm/Fs）及應用效率（Kw/Nm）兩項主要成分，本試驗中處理間的 Kw/Nm 值多無差異，表示植株所含每一單位氮素的子粒生產能力相近；除母本植株於低肥處理之 Kw/Nm 值較高外，父、母本自交系的 Kw/Nm 值均低於其雜交種，亦即基因型間具有差異，Kamprath *et al.*[13] 也曾於玉米氮肥試驗中有相同的報告，並據以解釋改良族羣增產的原因。

Table 6. Components of N use efficiency* of Corn hybrid Tainung 1 and inbreds TA3651—377 and TA2808—176 subjected to two levels of N-fertilization

Genotype	N Supplied (kg/ha)	Kw/Fs	Nm/Fs	Kw/Nm	Kw/Kn	Kn/Nm	Na/Nm	Kn/Na	Tw/Nm
Tainung 1	60	93.2 a**	2.24 a	41.6 b	62.4 b	0.67 a	0.70 a	0.96 c	91.9 b
	180	52.5 b	1.30 bc	41.2 b	58.3 bc	0.71 a	0.68 a	1.04 bc	79.8 c
TA3651—377	60	28.8 c	0.91 d	31.7 c	49.5 c	0.64 ab	0.26 c	2.46 a	113.5 a
	180	22.1 c	0.66 e	33.6 c	53.6 c	0.63 b	0.49 b	1.29 b	93.8 b
TA2808—176	60	50.2 b	1.01 cd	49.6 a	100.0 a	0.47 c	0.42 b	1.14 b	114.6 a
	180	29.7 c	0.84 de	35.4 c	67.7 b	0.52 c	0.51 b	1.02 bc	78.2 c

*Kw: kernel yield, Fs: amount of N fertilizer supplied, Nm: total N content in plant at maturity, Kn: kernel N content at maturity, Na: amount of N accumulated by plant after silking, Tw: whole plant dry weight at maturity.

**Means with the same letter within each column are not significantly different at 5% level by Duncan's New Multiple Range Test.

在氮素吸收效率方面，多數基因型間與氮肥處理間都有顯蓋差異， 亦即 Nm/Fs 比值為導致氮素利用效率變異的主要因素。吸收效率易受栽培條件左右，在品種改良方面也有其含義，Moll *et al.*[18] 即認為在重肥條件下進行育種選拔時，有利於吸收效率的表現， 但對應用效率則未施予任何選拔壓力，此類植株在氮肥供應不足時，子粒產量將甚為低落。

氮素應用效率可再予區分為 Kw/Kn 與 Kn/Nm 兩項成分，後者為氮素收穫指數，前者為子粒內每一單位氮素的對應子粒產量，兩者在各處理間的差異程度雖多未達顯著水準，但重肥處理略有偏低的趨勢，較低的 Kw/Kn 值（重肥處理及父本自交系）顯示子粒每累積一單位乾物質，需要較多量之氮素配合，此一特性之表現與子粒內 C/N 值有關，亦受基因型與氮素供應的影響[16,30]。由上述各項結果得知，在本試驗條件下，玉米氮素應用效率可能受到 Kw/Kn 與 Kn/Nm 兩項因子的共同影響。

本研究室多年來採用密植及重氮肥處理獲致高產的試驗中，肯定玉米於吐絲後之乾物質生產與氮素累積能力可維持植株旺盛的供源强度，以及證明目前推廣品種之產量仍然受限於積儲容積，但在氮素供需平衡關係對產量生理的作用方面，仍有不能確定之處。Sherrard *et al.*[27] 撰文討論經由育種方式改良玉米氮素利用效率的策略，認為如欲提高施用氮肥的增產效率，理想的玉米品種應該具有以下各項特性：(1)開花期具有最高的乾物質與還原態氮素含量，(2)開花期莖稈具有最高的硝酸態氮含量，(3)子粒充實期間具有最高的氮素吸收及同化功能，(4)氮素轉移至子粒的速率較高，(5)子粒充實期間的光合成速率較高，及(6)較長的子粒充實期，另一項可能有利的特性為較高的氮素收穫指數。上述各項條件涵蓋的範圍極為廣泛，其中可供參考及應用之處頗多，本試驗的部分目標亦與之符合；此外，鑑於臺農 1 號及臺農 351 號都是具有高產潛力的品種，如何經由對相關氮素生理作用影響產量表現方面的瞭解，及探討栽培與環境因子所可能導致的變異結果，以求發揮其產量潛能，有待今後繼續努力。

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Response of Nitrogen Assimilation and Utilization of Corn Hybrid Tainung 1 and Its Parental Inbreds to Two Levels of Nitrogen Fertilization[1]

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Summary

Corn hybrid Tainung 1 and its parential inbreds were cultured under two levels of N-fertilization (60 and 180 kg N/ha) to study the accumulation and partition of dry matter and N during their growth course. Components of N use efficiency were compared for the interpretation of yield performances. Heavy N-fertilization increased significantly the yields of dry matter and kernel, as well as harvest index at harvest, for Tainung 1 and its parental inbreds. Amount of dry matter produced after silking accounted for over 60% of total dry matter, or at least 1.25 times the dry weight of kernels for Tainung 1 suggesting active assimilation of photosynthates for the demands of kernel-filling. Dry matter produced after silking for paternal inbred of Tainung 1 was equivalent to 1.7 times the dry weight of kernels, implying severe limitation of kernel yield by sink ability. N concentrations of vegetative and reproductive organs of the paternal inbred exceeded those of hybrid Tainung 1 and the maternal inbred. It was suggested that the corresponding rates of accumulating carbohydrates and N by kernels of the three genotypes were different. Total amount of N accumulated by Tainung 1 was as high as 230 kg/ha under heavy N-fertilization. Harvest N index, which was consistent under the experiment treatment, ranged from 0.67 to 0.71. For maternal inbred, the index was onfy 0.47—0.52, while partition rations of N in the husks and cob were significantly higher than those of the other two genotypes. The differences in their post-silking abilities of assimilating C and N was reflected by the differences in C/N ratio of the kernels. The amount of N assimilated by Tainung 1 during kernel-filling accounted for over 60% of total N present at harevst, which was equivalent to the amount of N accumulated by the kernels. A balanced status of N assimilation and demand was therefore suggested. N use efficiency was highest for hydrid Tainung 1 than the two parental indreds. The major influencing factors were N uptake efficiency and the amount of dry matter produced in response to unit N accumulated by the kernel. N uptake efficiency decreased with increasing N-fertilization. Improving the N use efficiency of paternal inbred for possible improvement of hybrid yield performance was proposed.

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鉀肥種類與用量對藺草品質與產量之影響[1]

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摘要：於藺草臺農選1號之生育中、後期，配合氮肥施用鉀肥，每公頃施用鉀素（K_2O）量為75、150、225及300kg/ha 四種變級，分別以氯化鉀施用（A）125、（B）250、（C）375與（D）500kg/ha，及以硫酸鉀施用（E）150、（F）300、（G）450與（H）600kg/ha，計八種處理，並以不施鉀肥區（I）為對照，探討對藺草品質與產量之影響。結果發現一、二級草總和莖數率（100cm 以上）以施用250kg/ha 氯化鉀處理最高，對藺草品質之提昇有最好的效果。每公頃乾草產量以施用氯化鉀 375kg/ha 處理稍高，唯長草量較低。施用鉀肥確可提昇藺草品質，但對產量影響較小。肥效比較發現施用氯化鉀之肥效有比硫酸鉀優異之趨勢，顯示藺草品質似受氯根之影響較不明顯。鉀素利用率對藺草品質與產量並無直接影響，但鉀素吸收量與植體含鉀濃度均與長草率有顯著相關。

栽培藺草（*Juncus effusus* L. var. *decipiens* Buchenen）除應注意產量外，如何提高品質以迎合市場需要，亦為當前研究之重要課題。藺草之品質可因栽培地區、氣候及品種特性之不同而有差異，早期之栽培方法及施肥準則[5] 並不能完全適用，經本所進行一系列試驗後已有改善[3]，但對提昇藺草品質之效果仍然有限。理想之藺草品質以一、二級草（長度分別為120cm 以上及100—119cm）平均莖數率在 50%以上，而三級草（75—99cm）平均莖數率在 40%以下者為佳；然而目前藺草之三級草量佔相當高之比率，素為製蓆業者所詬病，蓋因三級草僅能提供編織中繼表及花蓆，此等低級產品在當今生活品質提高狀況下，勢將漸被淘汰。

藺草於生育中、後期為藺莖伸長及充實階段，在此階段一般均加强肥培管理，其中鉀肥促進藺草莖之伸長與充實的效果，在日本已有研究結果證實其相當顯著[7,8]，又有關鉀肥施用之準則，中野氏[7] 認為於5月上旬施用全量 20%，5月中旬為30%及6月上旬為50%較佳。但本省氣候與日本迴異，在二月中旬後氣溫回升較快，因此藺草生育進行較日本早30天左右，即兩地若採早植方式，同於12月上旬插植，則日本於5月上旬時始能行整刈作業，7月中旬前後才可收穫，而本省於4月上旬就可進行整刈工作，6月中旬以後開始收穫，因之本省藺草施用鉀肥時間通常均在4月中旬、5月上旬及5月中旬，其施用鉀肥種類均為氯化鉀，據包氏報告[1] 氯根常易影響植物品質，本省藺草之品質遲遲不能提昇，是否因施用鉀肥不當，或受氯根之影響，目前尚無人研究，爰以不同鉀肥與施用量，以藺草臺農選1號為供試材料，在藺草生育中、後期分次施用，詳加探討其對藺草品質與產量之影響，藉以改進省產藺草品質，以提供農民栽培之參考。

材料與方法

供試品種為藺草臺農選1號，鉀素（K_2O）每公頃施用量為75、150、225及300kg 等4種變級，

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3.本所農業化學系助理。

分別以氯化鉀施用（A）125、(B) 250、(C) 375及（D）500kg/ha，與硫酸鉀施用（E）150、(F) 300、(G) 450及（H）600kg/ha計8種處理，並以不施鉀肥區（I）做爲對照。試驗設計採逢機完全區集設計，4重複，每區集各9小區。行株距爲20×20cm 行長3m，14行區，小區面積8.4m²。於民國76年11月15日施用基肥並行整地，基肥量爲每公頃硫酸銨 200kg 及過磷酸鈣 600kg，插植前2天再行細整地及蓋平；11月19日以6本苗插植，插植深度 3—5cm，插植後4至6天內撒佈水田殺草劑（撒丹—M），每公頃施用30kg，插植後30天內經常保持水深4—5cm，以促進藺苗成活，此後之全生育期間，配合追肥時間行淺水灌溉，並適時間隔斷水7—10天，以增加土壤通氣性。

氮肥用量與施用時期係參照前報之試驗結果，即整刈前施用84kg與整刈後施用346kg/ha[4]。鉀肥於生育中、後期之4月15日、5月6日及5月16日三時期施用，每次施用量爲各處理之三分之一量。每一處理於6月中旬收穫時各取樣5叢，調查其最長莖長、莖徑（調查對象爲鮮草）、先枯長度、分級莖數率、公頃乾草產量（以收穫1m² 面積估算）、植體纖維含量及鉀濃度、土壤種植前後之鉀素濃度及鉀肥利用率等項目，其中分級草平均莖數率係按該5叢之一級草（120cm 莖數、二級草（100—119cm）莖數與三級草（75—99cm）莖數各佔有效草數之百分率估算之。

植體纖維之測定[6]，係將各處理之植體（100cm 以上之藺草莖）乾燥後磨碎，取1g 樣品脫去水分與脂肪後，經弱酸處理除去一部份蛋白質與半纖維（hemi-cellulose）以及所有糖分與澱粉，再經弱鹼處理除去剩餘之蛋白質與半纖維及木質素，最後經95%酒精洗滌並灰化後之失重定之，每處理均測定4次而求其平均。鉀成分吸收量乃以每公頃乾草量與植體含鉀素濃度之乘積估算之。植體鉀素濃度採用焰光分析法測定。鉀素利用率以如下公式計算：

$$\text{鉀素利用率} = \frac{(\text{施鉀肥區之鉀素吸收量}) - (\text{無鉀肥區之鉀素吸收量})}{(\text{鉀素施用量})} \times 100$$

結果與討論

一、藺草農藝特性表現：

試驗結果如表1所示，發現 B、C、D、E 及 H 處理區之最長莖長均顯著比無施鉀肥對照區（I）長，A、F、G處理區與對照區比較雖無顯著差異，但均稍長，顯示本所農田種植前之土壤，雖經測定含有33.73ppm 鉀素，若不施用鉀肥則仍無法充份供應藺莖伸長之需。至於兩種鉀肥不同用量間最長莖長比較，差異甚微，均未達顯著水準。分級平均莖數率方面，一級草平均莖數率最高者爲D處理，達6.3%，次爲B處理之5.6%，其餘各處理均較低，尤以不施用鉀肥時根本無一級草量。各處理之二級草平均莖數率均較對照區爲高，其中氯化鉀處理（A—D）及硫酸鉀 600kg/ha（H）與對照區之差異可達5%顯著水準，顯示施用鉀肥對藺草品質有提昇之趨勢。

一、二級草平均莖數率總合以B處理最高，達50.2%，次爲D、C處理，各爲47.3%及46.7%，分別比對照區增加23.5%、20.6%及20.0%，此三處理均爲施用氯化鉀，若與施用同量鉀素之硫酸鉀F、H及G處理比較，則分別增加8.3%、3.7%及12.0%，可見施用氯化鉀之肥效似比硫酸鉀優異，且不施用鉀肥區之品質大爲降低，其一、二級草平均莖數率之總合僅爲26.7%。至於三級草平均莖數率以 B、C 及 D 處理較低，各爲49.8%、53.3%及52.7%，尤其B處理比G及I處理減少15.5%及23.5%，顯現B處理一、二級長草率之總合較符合50%以上，且其三級草率最低之理想品質。

莖徑及先枯長度（length of rotted tip）兩性狀亦關係藺草品質甚大，因藺莖過細或先枯程度太嚴重，均會影響蓆面品質而降低市場價值。本研究之供試品種臺農選1號在辦理新品系示範[2]時所表現之乾草平均莖徑爲 1.30mm ，鮮草莖爲 1.50mm ，而在本試驗中各處理鮮草平均莖徑亦在1.50mm 左右，表現頗爲一致。因此莖徑大小受鉀肥種類及施用量之影響甚微。先枯長度則因處理不同而略有變化，其中以C 處理較長，達 4.10cm，而D及E處理（1.92cm及1.98cm）最短，其餘處理則均未達顯著差異，顯示鉀肥種類及施用量之不同多少會影響藺草的先枯長度，但其程度較小。

其次就公頃乾草產量而言，以C處理最高，達18,200kg/ha，次爲B處理之17,800kg/ha，再次爲H處理之17,500kg/ha與D處理之17,300kg/ha，雖然這些處理與對照區之間的差異均未達5%顯著水準，但鉀肥與乾草產量間之相關分析結果（r=0.6930*，圖1）顯示，施用鉀肥對藺草產量似有正面影響，即乾草產量隨著施用量增加亦有增加的趨勢。至於未施用鉀肥區的產量僅爲15,400kg/ha均比各處理區低。由此試驗結果可進一步佐證本省藺草田施用鉀肥似乎可提高產量，而施用氯化鉀肥效比硫酸鉀稍佳。施用鉀肥對藺草植體纖維含量之影響亦列於表1，以C、D與B處理最高，其每克植體所含纖維量與B、G、H及I處理之差異均達5%顯著水準，由此結果可推測C、D與E三處理之藺草品質應比其他處理爲佳；但從表1之長草總莖數率上未有明顯差異，此或可能植體纖維含量僅能影響藺草之彈性，對長度左右較小。

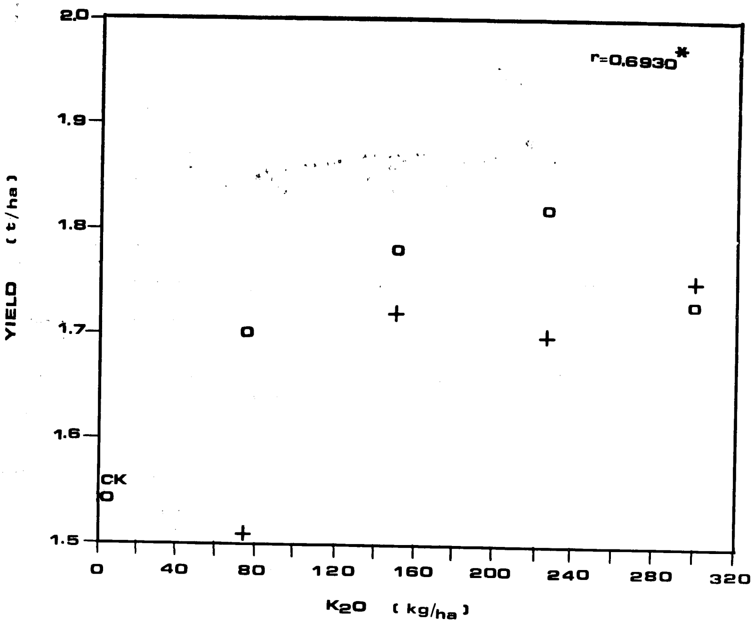

圖1. 鉀肥（K_2O）用量與藺草乾草產量間之相關分析。

Fig. 1. Relationsnhip between amount of K_2O applied and the dry straw yield of mat rush.

表1. 鉀肥種類與用量對藺草農藝性狀的影響

Table 1. Effects of type and amount of potassium fertilizer on the agronomic characters of mat rush

Treatment[1]	Stem Length (cm)	Stem Diameter (mm)	Length of Rotted Tip (cm)	Dry Straw Yield (kg/ha)	Grade[2] (% of total stem No.)				Fiber Content (%)
					1st	2nd	1st +2nd	3rd	
A	122.8	1.50	2.03	17,100	2.7	40.6	43.3	56.7	31.17
B	124.8	1.53	3.40	17,800	5.6	44.6	50.2	49.8	30.36
C	125.4	1.53	4.10	18,200	4.0	42.7	46.7	53.3	33.06
D	124.4	1.58	1.92	17,300	6.3	41.0	47.3	52.7	33.04
E	124.3	1.50	1.98	15,100	4.8	38.4	43.2	56.8	33.79
F	122.1	1.50	2.26	17,200	3.5	38.4	41.9	58.1	31.72
G	122.1	1.55	2.57	17,000	2.4	32.3	34.7	65.3	30.32
H	124.0	1.48	3.44	17,500	3.0	40.6	43.6	56.4	29.25
I (CK)	116.5	1.50	2.36	15,400	0.0	26.7	26.7	73.3	30.33
LSD (5%)	7.0	0.09	1.78	3,200	4.1	12.0	12.8	12.6	2.50

[1]Rates of K_2O fertilization were 75, 150, 300 and 600kg/ha for A, B, C and D, respectively, applied as KCl, and for E, F, G, and H, respectively, applied as K_2SO_4. Treatment I was check with no potassium fertilization.

[2]Grass was graded according to straw length. 1st grade: over 120cm; 2nd grade: between 100 and 119cm; 3rd grade: between 75 and 99cm.

二、鉀素利用率比較：

根據包氏[1]之報告，鉀肥施用量增加，植物通常可充分吸收，但氮肥與磷肥則不同，若施用量增加，反見利用率減低，又鉀質在土壤中之行動與銨相似，在銨易於溶脫之土壤，施用鉀肥時亦有同樣溶脫之虞，因之，其利用率實有必要探討。表2顯示各處理植體鉀濃度均以施鉀區較不施鉀區爲高，鉀素吸收量表現亦然。在施鉀區間比較，發現此兩項特性有不規則變化，即植體鉀濃度及吸收量並無因多施鉀肥而增高之趨勢，但分析其相關性（表3），則發現鉀素吸收量與植體含鉀濃度有極顯著相關。若探究鉀素利用率的表現，則可明瞭藺草對不同鉀肥與用量之反應，表2中各處理鉀肥利用率以A處理（施用鉀素量爲75kg/ha之氯化鉀）最高，達51.85%，次爲B處理之34.47%，其餘各處理區均較低。

表2. 鉀肥種類與用量對藺草植株鉀素利用性狀的影響

Table 2. Effects of type and amount of potassium fertilizer on the potassium utilization characters of mat rush

Treatment[1]	K Concentration in Plant Tissue (ppm)	Amount of K Uptaked (kg/ha)	K Utilization Efficiency[2] (%)
A	592	101.3	51.9
B	641	114.1	34.5
C	543	98.9	16.2
D	590	102.2	13.3
E	506	76.5	18.7
F	566	97.3	23.3
G	483	82.2	8.8
H	492	86.2	7.9
I (CK)	405	62.4	—

[1]See Table 1 for description of treatments.

[2]Defined as the difference in uptake amount between treatment and check divided by the amount of K_2O fertilizer applied.

分析各處理收穫時土壤所含鉀素，依序爲 15.43、17.55、18.87、19.21、15.91、16.92、25.08 及18.54ppm ，均比種植前含量33.73ppm 低，顯示所施之鉀肥並不多量殘存於土壤，因此藺草之鉀素利用率偏低的結果，是否受無效草量之多寡之影響，或因固定於土壤及有溶脫現象而影響藺草的鉀素吸收，尚有待將來進一步研究。

表3. 藺草植體鉀濃度、吸收量及利用效率間之相關係數

Table 3. Correlation coefficients among concentration, uptake amount and utilization efficiency of K in mat rush

Character	K Uptake Amount	K Utilization Efficiency
K Concentration	0.9345**	0.6818
K Uptake Amount		0.5453

**Significant at 1% level.

三、鉀素利用率對植體纖維含量與產量影響：

若不考慮鉀肥種類及施用量之不同，則由表 4 之相關分析得知，鉀素利用率對藺草品質與產量並無直接影響，其相關係數均不顯著；而鉀素吸收量與植體含鉀濃度分別對藺草長草量有顯著正相關，但對藺草短草量呈顯著負相關，顯示兩者影響藺草品質，即鉀草鉀素吸收量多，其植體含鉀素濃度愈高，藺草長草量增加而短草量減少，因而可提高藺草品質。二種鉀素利用情形與植體纖維含量及產量間之相關係數，分析結果並不顯著，故植體纖維含量多寡與產量均不受鉀素利用率的影響。至於藺草最長莖長、莖徑及先枯長度與鉀素之利用間均無顯著相關，故亦不受鉀肥利用率的影響。

表4. 藺草植株鉀素利用性狀與農藝性狀間之相關係數

Gable 4. Correlation coefficients among K utilization characters and agronomic characters in mat rush

K Utilization Character	Stem Length (cm)	Stem Diameter (mm)	Length of Rotted Tip (cm)	Dry Straw Yield (kg/ha)	Grade[1] (% of total stem No.)				Fiber Content (%)
					1st	2nd	1st + 2nd	3rd	
Concentration	0.2385	0.2568	−0.0479	0.3809	0.5549	0.6919	0.7541*	−0.7454*	0.0715
Uptake Amount	0.2781	0.2936	0.2307	0.6846	0.4291	0.7199*	0.7225*	−0.7226*	−0.0986
Utilization Efficiency	−0.1243	−0.2494	−0.2267	0.0316	−0.0428	0.3838	0.3554	−0.3541	−0.0383

* and ** Significant at 5% and 1% levels , respectively.

結　論

綜合上述結果，可知本試驗施用鉀肥確可提昇藺草品質但對產量影響較小。比較不同鉀肥肥效，發現施用氯化鉀之肥效似乎有比硫酸鉀較優之趨勢，因此可推測藺草施用氯化鉀受氯離子之影響程度並不嚴重。至於其最適施用量之問題，從試驗結果似可推薦 B 處理之施用量，即每公頃以氯化鉀 250kg（150kg K_2O）分次於藺草生育之中、後期配合氮肥做追肥施用為較佳，其次可考慮採用最高產量之C處理施用氯化鉀375kg/ha（225kg/ha K_2O），唯此處理之長草量不如B處理。另外，左右品質的因素以鉀素吸收量與植體含鉀素為主，因藺草對鉀素吸收量多，植體含鉀量愈多，其藺草品質常可提昇。

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Effect of Type and Amount of Potassium Fertilizer on the Quality and Yield of Mat Rush (Juncus effusus L. var. decipiens Buchen)[1]

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Summary

The effects of KCl and K_2SO_4 fertilizers applied at the middle and late growing stages on the grass quality and yield of mat rush cv. Tainung No. 1 was studied. Four levels of K_2O, i.e., 75, 150, 225 and 300kg/ha, were applied for both KCl (designated as A, B, C and D treatments, respectively) and K_2SO_4 (E, F, G and H treatments, respectively) fertilizers. A check plot (treatment I) without K fertilization was also included. Experimental results inicated that treatment B (150kg K_2O/ha as KCl) produced more grass in the 1st and 2nd grades (with length over 120 and 100cm, respectively) but less grass in the 3rd (with length between 75 and 99cm) than other treatments. Treatment C (225kg K_2O/ha as KCl) gave the highest grass yield, however, the effect of K fertilization on yield was not significant in general. Treatments B and D (300kg K_2O/ha as KCl) were most effective in terms of the percentage of 1st grade grass produced. Based on the above results, potassium fertilization effected more on quality than on yield of mat rush grass. Comparison between the two types of K fertilizer revealed that KCl was superior to K_2SO_4 in mat rush production. The assumption that chloride ion did not affect grass quality was also proposed. The K utilization efficiency was not correlated to either the quality or yield of mat rush. However, K concentration in plant tissue and the amount of K uptaked were positively correlated to the percentage of grass of the 1st and 2nd grades.

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稻麴病發生生態與防治[1]

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摘要 民國七十二年第二期作田間調查的結果，水稻稻麴病罹病叢率達14.8%，罹病穗率10.0%，一稻穗中稻麴數1～8個，其中以1個(64.7%)及2個(20.6%)最多。稻麴的分佈，主要集中在中段(52.7%)及下段(34.4%)，罹病穗之穗重顯著減輕。民國七十七年第二期作調查結果，罹病穗率最高爲12.5%，最低爲2.3%，每穗稻麴數平均最高爲2.7個，最低爲0.3個，病原菌厚膜胞子在無菌水及水瓊脂之發芽均以 25°C 爲最佳，其次爲 30°C，再次爲 20°C。在水瓊脂之發芽率高達95%，在無菌水中之發芽率亦高達93%。厚膜胞子發芽之酸鹼度爲4～9，最適在5～8之間。黃色稻麴厚膜胞子之發芽率高於黑色厚膜胞子，黃色者發芽率高達93%；黑色者僅6%，有時黑色厚膜胞子甚至不發芽。厚膜胞子發芽能力在室溫 25～30°C 下最低保持26天，最高保持60天，一般在40～60天，其發芽率隨着保存時間之增加而減少，通常在一個月內發芽率佳，但往後發芽率就顯著下降。病原菌在馬鈴薯葡萄糖洋菜培養基上菌落生長緩慢，生長速度最快者約需5週的時間才能長滿9公分的培養皿。厚膜胞子發芽產生分生胞子，分生胞子在水瓊脂之發芽率可達10.6%，其發芽之酸鹼度以6～7最適。在田間行藥劑篩選，以75%四氯異苯腈及58%鋅錳滅達樂混合可濕性粉劑效果最佳。

水稻稻麴病 (*Ustilaginoidea virens*)，於1878年由 Cooke 首先報告，1887年以後陸續有本病之報告(7)。在中國古代亦有此病之記載，由於此病發生在最適宜的氣候條件下，特別是高濕多雨，與水稻生長的氣候相似，被故認爲在「好年冬」時才會發生本病，一般農民稱「稻麴」爲「穀母」。

日本早在 1950年代就已經開始本病的研究(1)，尤其是在岐阜大學的池上氏發表的報告最多。有關本病田間發生生態，菌絲生長對營養的需求，接種試驗及傳播途徑在國外已有報告(2-10)，但本省尚未有有關稻麴病的研究報告。因爲本病在過去僅零星發生，而且發病輕微，故不受重視。但是近年來在本省水稻田曾普遍發生，影響產量及品質。有鑑於此，乃對本病之生態及防治加以探討，並將所得結果寫成報告，藉供研究及防治之參考。

材料與方法

1.田間發病調查

民國七十二年第二期作在嘉義縣太保鄉、臺南縣東山鄉、官田鄉及臺南市安南區，每地區隨機選定有發生稻麴病之稻田十塊，每塊田（約20公畝）至少相隔一百公尺以上，每塊田由中間分爲四區，每區調查兩對角線，每隔5叢調查1叢，記錄罹病叢率，罹病穗率。在罹病穗上再分爲上、中、下三

1.臺灣省農業試驗所 研究報告第 1509 號。本研究部分經費承農委會 77農建一7.1一糧一11及78農建一7.1一糧一12計畫補助，特此誌謝。

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段，記載一病穗中稻麴的分佈情形。另在成熟期由田間採回病穗約一千穗，依每穗上有1、2、3、4及5個稻麴以上加以分類，並與無病之稻穗比較穗重。民國七十七年第二期作於臺南縣白河鎮及嘉義縣民雄鄉等調查八塊田，其方法與上述相同。

2.接種試驗

挑取稻麴黃色部分，移入水瓊脂平板培養基，用玻璃針掃開，置於室溫下（25～30°C），約經36～48小時，於解剖顯微鏡下觀察厚膜胞子發芽，挑取單一且有發芽之胞子，培養於糙米斜面培養基（糙米 200g 加水 500ml ，以果汁機打碎，加糖 10g，裝管殺菌）。取更新培養在上述培養基1週至10天長出分生胞子，將分生胞子以無菌水洗出，以注射筒注於溫室盆栽之孕穗期水稻臺農67號，接種後之水稻置於溫室內觀察。

3.厚膜胞子在水瓊脂及無菌水中於不同溫度下之發芽率

從臺南縣白河鎮水稻田收集之稻麴，取其上黃色部分之厚膜胞子行單胞分離，然後培養於試管中備用。取菌株 TP—2, TP—3, TP—8 及 TP—30 ，以無菌水做成胞子懸浮液，然後以吸管吸取1小滴置於載玻片上之水瓊脂及凹形載玻片上，放在10，15，20，25，30及 35°C 之定溫箱中，經1，2及3天後在150倍顯微鏡下鏡檢至少100個厚膜胞子，觀察其發芽情形，每處理每次3玻片，重複2次。

4.厚膜胞子在不同酸鹼度之水瓊脂發芽率

取菌株 TP—3, TP—8 及 TP—30 以無菌水做成胞子懸浮液，然後以吸管吸取1小滴置於載玻片上已調成不同酸鹼度之2％水瓊脂上，然後置於 25°C 之定溫箱中，經3天後鏡檢，其方法與試驗3相同。

5.稻麴黃色與黑色部分厚膜胞子在水瓊脂之發芽率

將同一稻麴黃色及黑色部分之厚膜胞子分別以無菌水做成胞子懸浮液，然後以吸管吸取1小滴置於載玻片上之2％水瓊脂，置於 25°C 之定溫箱中，經3天後鏡檢，其方法與試驗3相同。

6.厚膜胞子在室溫下之存活

由田間取回之稻麴，置於室溫下（25—30°C），每隔一週，取自固定稻麴之黃色厚膜胞子，做成胞子懸浮液，然後如試驗3在水瓊脂及無菌水上，經3天後觀察厚膜胞子發芽情形。

7.稻麴病菌菌落生長速度

先將菌株 PT—1, PT—5, CM—1 及 CY—2 培養於 PDA 平板上，待其生長15天後分別以打孔器（直徑0.6公分）打取菌絲塊置於培養皿中之 PDA 放在 25°C 之定溫箱中，每週量其菌落直徑。每處理3個培養皿，重複2次。

8.分生胞子之發芽

取稻麴之厚膜胞子做成胞子懸浮液，滴於水瓊脂平板上，用玻璃棒將胞子掃開，待其厚膜胞子長出分生胞子（約1天），再以玻璃棒將分生胞子均勻分散於平板上放在 25°C 之定溫箱中，5天後觀察其發芽情形。每處理3個培養皿，重複2次。

9.田間藥劑篩選試驗

民國七十二年第二期作於嘉義縣大林鎮設置試驗田，種植水稻臺農67號，田間設計採逢機完全區集，四重複，小區面積0.128公畝，於抽穗前及齊穗期各施藥一次，供試藥劑如表十三。民國七十七年第二期作於臺南縣白河鎮設置試驗田，田間設計及施藥期與民國七十二年第二期作相同，供試藥劑如表十四。試驗田於水稻成熟期調查罹病叢率。

試驗結果

1.田間發病調查

民國七十二年第二期作田間調查結果，罹病叢率平均最高為19.3%，最低為11.3%，平均為14.8

%。罹病穗率平均最高為14.9%，最低為7.6%，平均為10.0%（表一）。稻麴在病穗中以中段（52.7%）最多，其次為下段（34.6%），上段最少（12.7%）（表二）。

表一、田間稻麴病發生情形（民國七十二年第二期作）

Table 1. Occurrence of rice false smut under field condition (2nd crop, 1933)

地點 Location	罹病叢率 Diseased hill (%)	罹病穗率 Diseased panicle (%)
大林	12.0	8.9
東山	16.5	14.9
官田	11.3	8.6
安南	19.3	7.6
平均	14.8	10.0

表二、稻麴在病穗中之分佈

Table 2. Distribution of false smut on panicles

部位 Position	稻麴分佈百分率 % of false smut distribution
上段*	12.7**
中段	52.7
下段	34.6

*Panicle was divided into upper, middle and lower portions

**Average of panicles

在每病穗中稻麴之數目以1個最多（64.7%），其次為2個（20.6%）（表三）。稻麴之數目對穗重之影響，由於稻麴鄰近之不稔實粒的增加，所以對穗重有顯著的影響（表三）。

表三、病穗中稻麴之數目及其對穗重的影響

Table 3. Number of false smut in diseased panicles and its effects on weights of panicles

每穗稻麴數目 No. of false smut per panicle		平均穗重（克） Ave. wt. of panicle (g)
1	(64.7)*	2.5a**
2	(20.6)	2.4a
3	(7.6)	2.4a
4	(3.7)	2.1b
5	(3.4)	2.0b
0		2.9a

* Individual number of panicles with 1~5 false smuts/Total number of panicles×100%

** Means in the column followed by the same letter do not differ significantly according to Duncan's multiple test

民國七十七年第二期作田間調查罹病穗率最高爲12.5%，最低爲2.3%，平均爲5.1%。每穗稻麴數最高爲2.7個，最低爲0.3個，平均爲1.4個（表四）。

表四、水稻稻麴病發生情形

Table 4. Occurrence of rice false smut under field condition (2nd crop, 1988)

地點 Location	罹病穗率 % of diseased panicle	稻麴數／穗 No. of false smut/panicle
白河	4.5	1.6
白河	12.5	2.0
白河	3.9	0.7
白河	5.1	1.7
白河	3.6	0.9
民雄	6.1	2.7
民雄	2.3	1.0
民雄	2.6	0.3
平均	5.1	1.4

2.接種試驗

在所接種的60稻穗，三週後有8穗產生灰白色的稻麴，罹病穗率13.3%，每穗之稻麴數有1～2個。稻麴的色澤隨着稻穗的成熟終成黃褐色。

3.厚膜胞子在水瓊脂及無菌水中於不同溫度下之發芽率

稻麴病菌不同菌株厚膜胞子在水瓊脂之發芽率差異甚大，菌株 TP—2 及 TP—30 發芽率不高，菌株 TP—3 及 TP—8 發芽情形較好。一般發芽溫度範圍在15，20，25及 30°C ，尤其在20，25及 30°C 爲佳，在10及 35°C 發芽不佳（表五）。

表五、稻麴病菌厚膜胞子於水瓊脂上在不同溫度之發芽率（%）

Table 5. Germination of chlamydospores of *Ustilaginoidea virens* on water agar at different temperatures (%) [a]

Temperature °C	Isolate											
	TP-2			TP-3			TP-8			TP-30		
	1day	2day	3day	1day	2day	3day	1day	2day	3day	1day	2day	3day
10	1.3	2.6	1.9	0	1.5	0	0	0	4.5	1.2	1.3	2.5
15	1.1	2.3	2.8	14.6	15.5	14.9	35.5	38.6	24.7	0	1.4	2.6
20	1.6	1.8	2.5	10.2	12.4	21.6	70.3	77.4	89.9	2.8	2.9	1.9
25	6.7	5.6	6.9	23.3	30.6	49.8	82.6	85.3	90.5	10.3	40.2	42.5
30	1.0	2.0	2.5	10.5	24.6	41.3	67.1	83.6	95.1	3.0	4.0	4.2
35	0	0	3.6	0	0	0	0	0	12.2	0	0	1.3

[a] Three slides for each treatment, experiments were conducted 2 times.

厚膜胞子在無菌水中之發芽率差異亦甚大，一般其發芽率比在水瓊脂中之發芽率爲低，在無菌水中之發芽率仍以 TP—8 爲最佳（表六）。

表六、稻麴病菌厚膜胞子於無菌水中在不同溫度之發芽（%）

Table 6. Germination of chlamydospores of *Ustilaginoidea virens* on sterilized distilled water at different temperature (%)[a]

Temperature °C	Isolate											
	TP-2			TP-3			TP-8			TP-30		
	1day	2day	3day	1day	2day	3day	1day	2day	3day	1day	2day	3day
10	0	0	0	0	0	1.2	0	0	17.4	0	0	1.3
15	0	0	0	2.1	5.3	7.8	13.1	14.6	17.8	0	0	2.4
20	1.0	1.0	1.2	5.2	6.4	13.5	61.5	67.6	77.1	2.0	4.2	7.3
25	1.0	2.3	4.5	4.9	9.2	10.3	63.4	88.5	89.4	1.0	1.5	14.2
30	1.1	1.4	2.8	5.1	12.3	13.6	58.2	57.4	93.2	1.2	1.3	3.2
35	0	0	0	0	0	0	0	0	0	0	0	0

[a] Three slides for each treatment, experiments were conducted 2 times.

4.厚膜胞子在不同酸鹼度之水瓊脂發芽率

厚膜胞子發芽之適宜酸鹼度在 5－8 之間，三個菌株之發芽率仍以 TP—8 爲最高（表七）。

表七、稻麴病菌厚膜胞子於不同酸鹼度之水瓊脂中放置在 25°C 之發芽率（%）[a]

Table 7. Germination of chlamydospores of *Ustilaginoidea virens* on different pH value of water agar at 25°C (%)[a]

Isolate	pH value					
	4	5	6	7	8	9
TP—3	5.2	13.6	14.8	27.5	12.2	9.0
TP—8	29.6	95.4	93.6	82.7	65.5	32.0
TP—30	3.2	8.0	6.3	6.2	4.3	4.2

[a] Three slides for each treatment, experiments were conducted 2 times.

5.稻麴黃色與黑色部份厚膜胞子在水瓊脂之發芽率

同一稻麴黃色部份厚膜胞子發芽率優於黑色部份厚膜胞子之發芽率。取自白河之稻麴黃色部份厚膜胞子之發芽率達93.3%，但黑色部份厚膜胞子之發芽率僅 6.5%。由民雄取回之稻麴黃色厚膜胞子之發芽率爲30.6%，而黑色部份之厚膜胞子則不發芽（表八）。

6.厚膜胞子在室溫下之存活

由田間採回12個稻麴在室溫 25～30°C 下厚膜胞子發芽能力最低保持26天，最高保持60天，一般在40～60天。其發芽率隨着保持時間之增加而減少。通常在一個月內發芽率佳，但此後發芽率就顯著下降（表九）。

表八、自然稻麴黃色與黑色厚膜胞子在水瓊脂於 25°C 之發芽率（%）

Talbe 8. Germination of yellow and black chamydospores of *Ustilaginoidea virens* on water agar at 25°C (%)[a]

Location	Inoculum	
	Yellow chlamydospore	Black chlamydospore
白　河	93.3	6.5
民　雄	30.6	0

[a] Three slides for each treatment, experiments were conducted 2 times.

表九、稻麴病菌厚膜胞子在室溫下（25—30°C）[a] 之存活

Table 9. Survival of chlamydospores of *Ustilaginoidea virens* at room temperature (25—30°C)

Location	Date	Testing					date				
		June 7		June 14		June 21		June 27		July 4	
		WA	W[b]	WA	A	WA	A	WA	A	WA	A
白　河	88—5—31	98.0	48.0	95.0	40.0	81.8	37.6	77.9	33.5	76.6	30.4
白　河	88—6—01	97.0	68.0	84.0	47.2	82.8	21.7	73.8	13.2	60.3	13.7
嘉　義	88—6—02	99.0	66.5	86.2	14.0	95.4	10.8	89.7	7.1	84.9	13.3
嘉　義	88—6—06			76.3	4.0	59.3	3.8	36.3	1.7	14.0	0.4
嘉　義	88—6—07			97.4	56.0	91.1	10.7	82.0	6.0	18.0	4.7
嘉　義	88—6—09					92.6	1.6	83.7	3.2	11.1	2.8
嘉　義	88—6—10					90.2	19.5	60.9	4.5	25.7	3.3
嘉　義	88—6—11					96.5	8.6	73.5	1.5	85.0	1.8
白　河	88—6—14					84.7	11.8	76.5	8.1	80.2	6.8
白　河	88—6—15							82.3	15.6	77.6	15.5
宜　蘭	88—6—24									7.9	0
嘉　義	88—6—30										

Location	Date	July 11 WA	July 11 A	July 18 WA	July 18 A	July 25 WA	July 25 A	Aug. 1 WA	Aug. 1 A	Aug. 8 WA	Aug. 8 A
白河	88—5—31	53.9	2.4	12.6	0	2.8	1.9	3.9	0	0	0
白河	88—6—01	32.6	4.2	2.0	5.2	1.3	0.4	0	0	0	0
嘉義	88—6—02	81.7	2.1	22.6	0.3	7.0	2.9	2.9	0	0	0
嘉義	88—6—06	9.4	0	0	0	0	0	0	0	0	0
嘉義	88—6—07	17.9	0.3	0.2	0	0	0	0	0	0	0
嘉義	88—6—09	0.8	0	0.2	0	0	0	0	0	0	0
嘉義	88—6—10	2.2	0	1.3	0	0	0	0	0	0	0
嘉義	88—6—11	24.1	1.3	0.2	0.2	0	0	0	0	0	0
白河	88—6—14	46.3	1.5	2.5	1.7	2.0	0	0	0	0	0
白河	88—6—15	4.1	6.2	0	0	0	0	0	0	0	0
宜蘭	88—6—24	1.9	0.4	3.5	0	0.2	0	2.5	0	0	0
嘉義	88—6—30	80.2	11.6	65.3	5.4	34.6	2.0	5.6	0	0	0

Testing date

[a] Germination of chlamydospores

[b] WA: Water agar W: Sterilized distilled water

7.稻麴病菌菌落生長速度

稻麴病菌在 PDA 培養基上生長速度緩慢，生長速度最快者約需 5 週的時間才能長滿 9 公分的培養皿，有的菌株生長速度緩慢，5 週後菌落之大小僅6.0×6.1公分（表十）。

表十、稻麴病菌在 25°C 下菌落生長速度（公分）

Table 10. Mycelial growth of *Ustilaginoidea virens* (cm) at 25°C

Isolate	Incubation period (wk) 1	2	3	4	5
PT—1	1.3×1.3	3.2×3.4	6.2×6.8	7.3×7.7	8.9×9.0
PT—5	1.9×1.9	2.6×2.5	4.4×3.9	5.0×4.9	6.0×6.1
CM—1	1.7×1.7	3.7×3.7	6.0×6.3	7.1×7.6	8.6×8.7
CY—2	1.6×1.8	3.7×3.7	4.9×5.0	5.9×6.1	7.2×7.4

8.分生胞子之發芽率

厚膜胞子發芽後產生分生胞子，分生胞子之發芽率不高，菌株 TP—3, TP—8 及 TP—30 發芽率各爲4.2，6.7及5.3%（表十一）。

表十一、水稻稻麴病菌分生胞子在 WA 上於 25°C 之發芽率（%）[a]

Table 11. Germination of conidia on water agar at 25°C (%)[a]

Isolate	Germination
TP—3	4.2
TP—8	6.7
TP—30	5.3

[a] Three slides for each treatment, experiments were conducted 2 times

分生胞子在不同酸鹼度之發芽率以 6 及 7 發芽最佳，但發芽率不高，發芽率最高者僅10.6%（表十二）。

表十二、水稻稻麴病菌分生胞子在不同酸鹼度下於 25°C 之發芽率（%）[a]

Table 12. Germination of conidia on different pH values of water agar at 25°C [a]

Isolate	pH value						
	3	4	5	6	7	8	9
TP—3	0	0	0	10.6	7.7	0	0
TP—8	0	0	2.5	5.4	4.2	0	0
TP—30	0	0	1.2	3.6	4.0	0	0

[a] Three slides for each treatment, experiments were conducted 2 times.

9. 田間藥劑篩選試驗

民國七十二年第二期作篩選結果，以75%四氯異苯睛可濕性粉劑，80%四氯丹可濕性粉劑，58%鋅錳滅達樂可濕性粉劑及33%鋅錳乃浦可濕性粉劑等四種藥劑之藥效最佳（表十三）。

表十三、不同殺菌劑對稻麴病之防治效果（民國七十二年第二期作）

Table 13. Efficacy of fungicides for the control of rice false smut disease (2nd crop, 1983)

Fungicides	% of diseased hill
50% Benlate WP. 1000X	1.4 bc[a]
72.5% Cuprosan 311 Super D WP. 1000X	0.1 a
75% Daconil WP. 500X	0 a
65% Bavistin-C WP. 1000X	0.1 a
80% Difolatan WP. 500X	0 a
80% Mancozeb WP. 400X	0.6 b
58% Ridomil-MZ WP. 400X	0 a
80% Alliette WP. 500X	2.7 c
33% Mancozeb FP. 400X	0 a
Control	1.3 bc

[a] Means in the column followed by the same letter do not differ significantly according to Duncan's multiple test

民國七十七年第二期作篩選結果，以75%四氯異苯腈可濕性粉劑及58%鋅錳滅達樂可濕性粉劑防治效果最佳，其罹病叢率僅爲0.2及0.3%（表十四）。

表十四、不同殺菌劑對稻麴病之防治效果（民國七十七年第二期作）

Table 14. Efficacy of fungicides for the control of rice false smut disease (2nd crop, 1988)

Fungicides	% of diseased hill
50% Benlate WP. 1000X	2.6 b[a]
75% Daconil WP. 500X	0.2 a
65% Bavistin-C WP. 1000X	1.5 b
58% Ridomil-MZ WP. 400X	0.3 a
80% Alliette WP. 500X	3.8 bc
80% Mancozeb WP. 400X	2.9 b
35% Hinodan WP. 1000X	2.8 b
50% Hinosan EC. 1000X	4.1 c
Control	5.3 c

[a] Means in the column followed by the same letter do not differ significantly according to Duncan's multiple test

討　　論

稻麴病近年來在本省各地區曾普遍發生，影響稻米的生產。民國七十二年第二期作罹病穗率最高達10%，民國七十七年第二期作罹病穗率達12.5%，罹病穗之穗重顯著減輕，故可知稻麴病可影響米質及產量。稻麴病菌厚膜胞子在水瓊脂或無菌水中之發芽，菌株間之差異很大，本試驗中以菌株 TP—8發芽率最高。發芽溫度以 25°C 最適，酸鹼度以 5 — 7 最適，黃色稻麴厚膜胞子之發芽率優於黑色稻麴之厚膜胞子，本報告所提到的黑色厚膜胞子可能和日本所提到之綠色厚膜胞子相似 (1) 。厚膜胞能芽發子力最低保存26天，最高保存60天，日本報告在低溫下可保存十個月 (1) 。在日本報告 (5) 有 5 —10%之稻麴會帶有菌核，而由菌核產生子囊胞子做爲第一次感染源，厚膜胞子做爲第二次感染源，或在秧苗期就以厚膜胞子接種，在抽穗期亦會產生稻麴 (4) 。但目前從田間採回之稻麴尚未看到菌核，所以在臺灣以何種型態之病原爲感染源尚不清楚。不過依據病原菌生長的速度甚爲緩慢，以及稻麴在接種後三週才開始形成，若由稻麴上之厚膜胞子再做爲第二次感染源似乎不太可能。在藥劑篩選，由兩年之結果顯示75%四氯異苯腈可濕性粉劑及58%鋅錳滅達樂可濕性粉劑防治效果最佳。

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Ecology of rice false smut disease and its control[1]

W. H. Tsai[2], C. C. Chien[2] and S. C. Hwang[3]

According to the survey of rice false smut disease of 2nd crop in 1983, it showed that the percentage of diseased hill was 14.8%, and the percentage of diseased panicle was 10.0%, individually. The number of smut balls on a panicle was from one to eight, but the majority was one smut (64.7%) and two smuts (20.6%). The distribution of smut balls was concentrated in the middle portion (52.7%) and lower portion (34.4%) of a panicle. The diseased panicle weight decreased significantly. Moreover based on the 2nd crop of 1988, it indicated that the highest percentage of diseased panicle was 12.5% , and the lowest was 2.3%. The highest average number of smut balls was 2.7 per panicle, and the lowest was 0.3 per panicle. On the other hand, the germination of chlamydospores on both sterilized distilled water and water agar was best at 25°C, followed by 30°C and 20°C, respectively. The germination percentage was 95% on water agar and 93% in sterilized distilled water. The range of pH value for germination was 4-9, and the optimal was 5-8. The germination of yellow chlamydospores was much better than that of black chlamydospores, it reached up to 93% for yellow chlamydospores, but only 6% was obtained for black chlomydospores. Sometimes the black chlamydospores even didn't germinate at all. The chlamydospores survived at least 26 days at room temperatures (25—30°C), but the rang was between 40 and 60 days, in general. The germination decreased with increasing times. The fungus colony grew slowly on PDA medium in Petri dishes. It took about five weeks to cover the surface of a 9-cm Petri dish. The chlamydospores produced conidia after germination, the percentage of conidial germination on water agar was 10.6%, and the optimal pH value for germination was 6-7. The chemical control under field test showed that 75% Daconil WP and 58% Ridomil-MZ WP obtained the best control of this disease.

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葡萄晚腐病菌之致病性[1]

段中漢[2]　謝文瑞[3]

摘要：葡萄晚腐病是由 *Glomerella cingulata* 所引起。本病爲本省葡萄栽培上最重要的果實病害之一。病原菌於高溫多雨的氣候下，經常造成葡萄產業的嚴重損失。由不同地區分離所得的晚腐病菌接種至田間各生長期的『巨峰』葡萄果實，均能造成感染，並表現病徵。在接種葡萄幼果後呈現壞疽斑點的部位，可發現其果肉組織內有菌絲的生長，並能產生少量的分生孢子。而病原菌在果實組織內蔓延的速度是隨果實成熟度的提高而加快。影響病原菌在不同生長期果實組織內蔓延速度差異的原因，應是來自果實汁液組成分的變化。由採收前六週至採收前一週，『巨峰』葡萄果實汁液的pH值由2.93增至3.56，糖度則由3.8增至16.7；而菌絲的生長量則驟增17倍。果實汁液內糖度的急劇增加及有機酸含量的降低，可能是造成晚腐病菌在葡萄成熟果實內快速生長的重要因子。

關鍵詞：葡萄、晚腐病菌、病原性、潛伏感染

本省葡萄栽培以鮮食爲主，而『巨峰』是最主要的栽培品種，但由於受到晚腐病之爲害，以致經常造成嚴重的損失。晚腐病之爲害部位以果實爲主，受害的葡萄果實最初於果皮上產生淡褐色水浸狀斑點；隨後，病斑逐漸擴大，至果實成熟期則產生大量橙紅色、黏性的分生孢子堆 (acervulus)，受害果實因而腐爛。由於晚腐病在果實成熟期發病非常迅速，如遇連續降雨，大量的分生孢子藉雨水飛濺而傳播，極易於短期間內，造成嚴重的損失，故爲本省葡萄產業極具威脅性的病害。

葡萄晚腐病是由*Glomerella cingulata* (Ston.) Spauld et Schr. 所引起，其無性世代爲*Colletotrichum gloeosporioides* Penz.，即通稱的炭疽病菌。由炭疽病菌所引起的作物病害常有潛伏感染 (latent infection) 的現象[4,15,16,17]。如香蕉炭疽病 (*Colletotrichum musae*)[2,8]，葡萄柚，芒果，酪梨及木瓜的炭疽病(*C. gloeosporioides*)[5,6,10,17]。但桃樹炭疽病(*Glomerella cingulata*)[13]，蘋果苦腐病 (*G. cingulata*)[11]，草莓炭疽病 (*C. fragariae*)[9]，玉米炭疽病 (*C. graminicola*)[12] 則不爲潛伏感染。葡萄晚腐病是否爲潛伏感染，是一值得深入探討的問題。是項問題對於本病防治措施之釐訂，具有關鍵性的影響，因此，亟待加以澄清。

葡萄果實成分複雜，當其由青綠轉至成熟時，果實成分中變化最顯著的，就是糖度 (Brix) 及酸鹼度 (pH value)。這些成分的變化對於田間晚腐病之發生影響如何，更待試驗加以澄清。本文之目的在藉接種試驗及不同齡期果實成分中糖度及酸鹼度對應晚腐病菌生長之觀點，探討晚腐病菌對『巨峰』葡萄的致病性，並以潛伏感染作爲問題的核心，以期對晚腐病菌之致病性有更深入的瞭解。

材料與方法

一、田間觀察及病原菌之分離與培養

1.臺灣省農業試驗所　研究報告第1510號。本文內容爲第一作者碩士論文之一部分。
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自民國七十一年三月起，定期前往本省中部各葡萄產區，調查葡萄果實各生長期晚腐病的發生情形。並採取各地之罹病果實，以單孢分離法（single conidium isolation），分離病原菌。分離所得之菌株培養於馬鈴薯葡萄糖瓊脂培養基（Potato-Dextrose Agar, PDA），置於室溫及間接光照的環境下，並定期以單孢作更新培養。

二、晚腐病菌對不同生長期葡萄果實的病原性

在臺中縣新社鄉試區，於『巨峰』葡萄著果後二週起，至採收前一週止，計十週。每週以分離自卓蘭之晚腐病菌（CL-01）接種葡萄果實，每次接種四果房，以探討晚腐病菌對不同齡期果實的病原性。接種方法是將培養於PDA上的葡萄晚腐病菌以無菌水洗下其分生孢子，並稀釋至每毫升含10^5個分生孢子。將孢子懸浮液以塑膠製手壓噴霧器直接噴至田間『巨峰』葡萄果實的表面。再套以塑膠袋保持濕度三天。取下套袋後，觀察病徵之發展。另以無菌水噴果房作爲對照。

三、晚腐病菌不同菌株對葡萄幼果之病原性

以分離自東勢、卓蘭、大村、溪湖、新社及信義等六個主要葡萄產區的晚腐病菌爲供試菌。於每地區所分離者，任意選取五個菌株，計30個菌株，分別接種新社試區之田間著果後約六週（豌豆期至硬核期）的葡萄果實，每菌株接種3果房，以探知不同來源之晚腐病菌對幼果期葡萄之病原性。

四、晚腐病菌在葡萄幼果組織內的存活

以分離自卓蘭之CL-01及大村之TC-03二菌株分別接種田間『巨峰』葡萄著果後四週之幼果，接種後，除每週記錄其病徵外，同時採回接種之果實進行切片觀察。以探知病原菌侵入幼果後，在其侵入部位的存活情形。

五、不同果齡葡萄汁液對晚腐病菌生長的影響

於葡萄採收前六週迄採收前一週，每週前往田間採取葡萄果實，洗淨後榨汁，並以四層紗布過濾，將所得濾液再分裝至容量爲125毫升之三角燒瓶中，每瓶50毫升，以高壓殺菌法（121°C, 15min）消毒培養基。各次處理所得之培養液於計錄其糖度（Brix）及酸鹼度（pH value）後，再將晚腐病菌（CL-01）單孢移入培養液中。於室溫下，靜置培養三週，秤其菌絲乾重量。每處理四重覆。

六、糖度與酸鹼度對晚腐病菌生長的影響

以不含葡萄糖（glucose）之 Czapek's 培養基（$NaNO_3$ 3.0g, K_2HPO_4 1.0g, $MgSO_4 \cdot 7H_2O$ 0.5 g, $FeSO_4 \cdot 7H_2O$ 0.01g，蒸餾水1,000ml）爲基礎培養基。以Citric acid-Na_2HPO_4緩衝溶液調整培養基之酸鹼度爲2.9及3.4。並以不同量之葡萄糖調整上述兩組培養基之糖度分別爲3.8，5.8，7.8，9.8，11.8，及13.8，使成12種不同酸鹼度及糖度之組合。各處理之培養基均以50毫升之量分裝於容量爲 125 毫升之三角燒瓶中。經高壓殺菌後，再以晚腐病菌（CL-01）單孢移入培養基中，靜置培養三週，秤其菌絲乾重量。每處理四重覆。

結　果

一、田間病徵

葡萄晚腐病以果實爲主要感染對象。幼果期之病徵，初爲黑褐色，水浸狀斑點；嗣後，病斑隨果實生長而漸成分枝狀擴大。如果實在近成熟期才受到感染，則初期果皮也會出現黑褐色斑點，但病勢進展非常迅速，病斑成圓形向外擴大，且其上很快就會出現許多橙紅色的分生孢子堆（acervulus），成同心輪紋狀，排列在果皮上（圖一）。幼果受感染者至其成熟期，亦會有大塊病斑及產生橙紅色孢子堆之症狀。罹病果實最後均會皺縮，乾枯。或落果或呈木乃伊狀掛於枝條上。經由接種試驗得知，晚腐病菌亦可感染葡萄的葉片，卷鬚，果梗，葉柄及花器等部位，唯病徵僅爲黑褐色小點，不會擴大，且始終未見有分生孢子堆在病斑上產生。

圖一、「巨峰」葡萄果實受到晚腐病菌感染之典型病徵。

Fig. 1. Typical symptoms of "Kyoho" grape berries infected by *Colletotrichum gloeosporioides*.

二、晚腐病菌對不同生長期果實的病原性

晚腐病菌接種到不同生長期的「巨峰」葡萄果實後發現，各齡期的果實皆會發病。葡萄果實接種晚腐病菌後，經3～4天即在果皮上產生黑褐色斑點，唯病斑擴大速率因果齡而異。在幼果上，其病斑擴大較慢；而熟果上，其病斑擴大較快。亦即在接種後經一段時間之變化，在幼果上接種者，其病斑較小；在熟果上接種者，其病斑較大。這些接種的果實至其發病後期，於果皮上均會產生大量橙紅色的孢子堆。隨後，病果皺縮凹陷，呈現典型的晚腐病病徵。至於發病率，則各時期接種者，每果房的罹病率均達50%以上（表一）。

表一、晚腐病菌接種不同生長期「巨峰」葡萄果實的結果

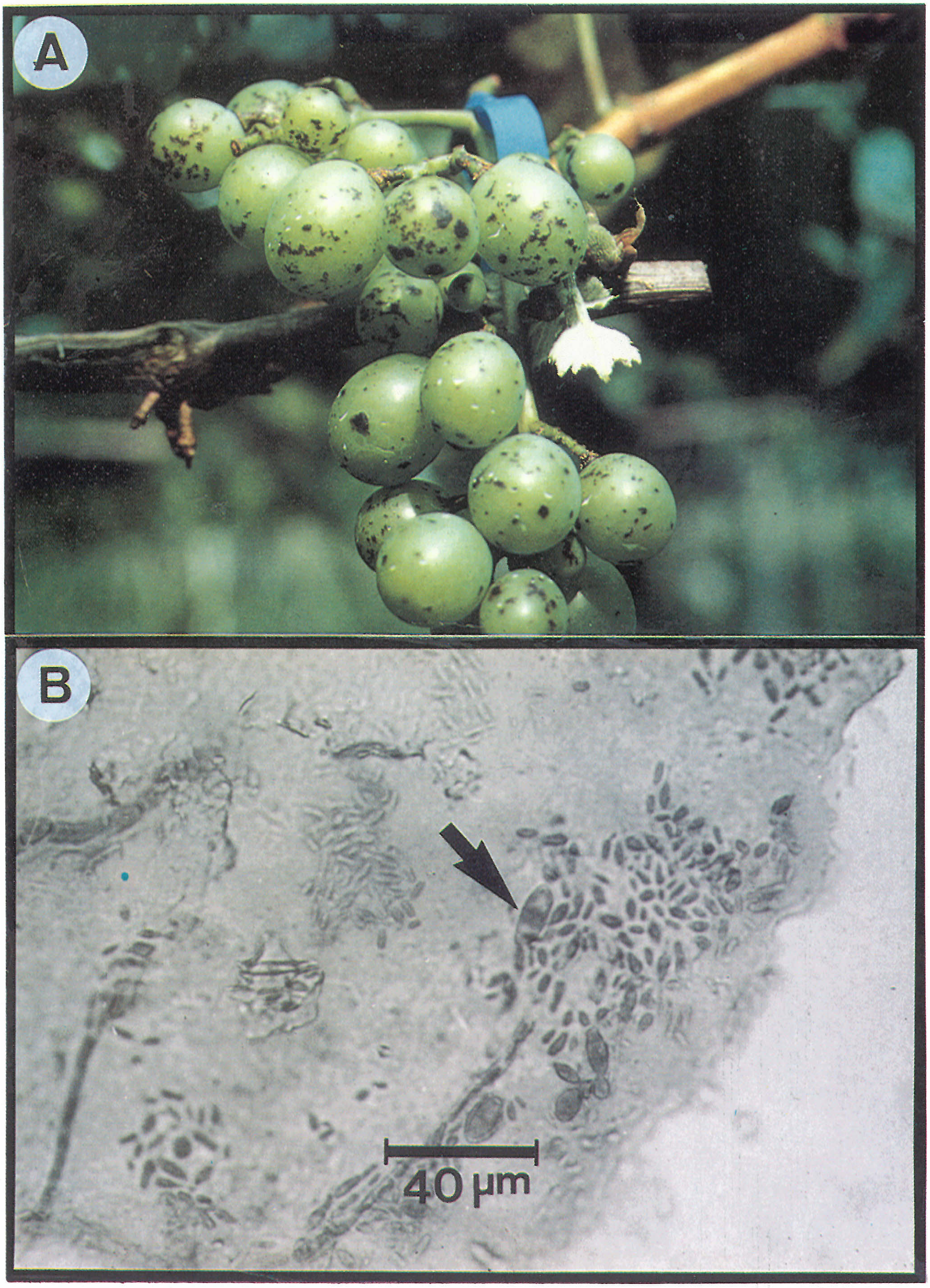
Table 1. The results of inoculation of *Colletotrichum gloeosporioides* on different growing stages of "Kyoho"

Time[a] (WK)	Disease incidence[b] (%)				
	I	II	III	V	Average[c]
2	85	90	55	63	73 b
3	83	86	70	83	81 ab
4	64	88	85	88	81 ab
5	91	76	88	95	88 ab
6	82	69	89	100	85 ab
7	66	85	90	68	77 ab
8	87	88	86	70	83 ab
9	90	60	86	85	80 ab
10	85	87	92	100	91 ab
11	95	100	86	88	92 a

[a] Weeks after fruit set.
[b] Disease incidence = No. diseased fruits/No. inoculated fruits per cluster of grape berries × 100%.
[c] Values followed by the same letter are not significantly different according to Duncan's multiple range test, P=0.01.

三、晚腐病菌不同菌株對葡萄幼果的病原性

自東勢等六個地區的葡萄果實上分離所得的三十個晚腐病菌菌株分別接種田間著果後六週之葡萄幼果均能造成感染，且每果房罹病果粒數均達1／2以上。



圖二、「巨峰」葡萄著果後四週之幼果接種晚腐病菌三週後的病徵 A. 果實外部病徵。B. 病原菌在果皮下生長並產生孢子（箭號）。

Fig. 2. *Colletotrichum gloeosporioides* on "Kyoho" four weeks' green berry at three weeks after artificial inoculation. A, Symptom. B, Mycelia and conidia (arrow) of the pathogen under the peel of green berry.

四、晚腐病菌在葡萄幼果組織內的存活

晚腐病菌的分生孢子接種至「巨峰」葡萄的幼果後，經 6 ～10小時即在果皮上發芽並形成附著器。3 至 5 日後可在果皮上產生明顯的黑褐色斑點。此後，病斑隨果實生長而日漸擴大。鏡檢幼果病斑組織，可見菌絲在病斑部位逐漸蔓延，並於接種後第三週可見組織內有少量的分生孢子形成，但表皮外仍未見有分生孢子產生（圖二）。

五、不同果齡葡萄汁液對晚腐病菌生長的影響

葡萄果實於採收前六週，其汁液酸鹼度（pH value）由 2.93，升高至採收前一週的3.56，增加0.63；而糖度（Brix）則由3.8增至16.7。增加最快的是在採收前第四週，由4.1增至11.1。病原菌的生長前後增加達17倍之多（表二）。

表二、不同果齡葡萄的汁液對晚腐病菌菌絲生長之影響

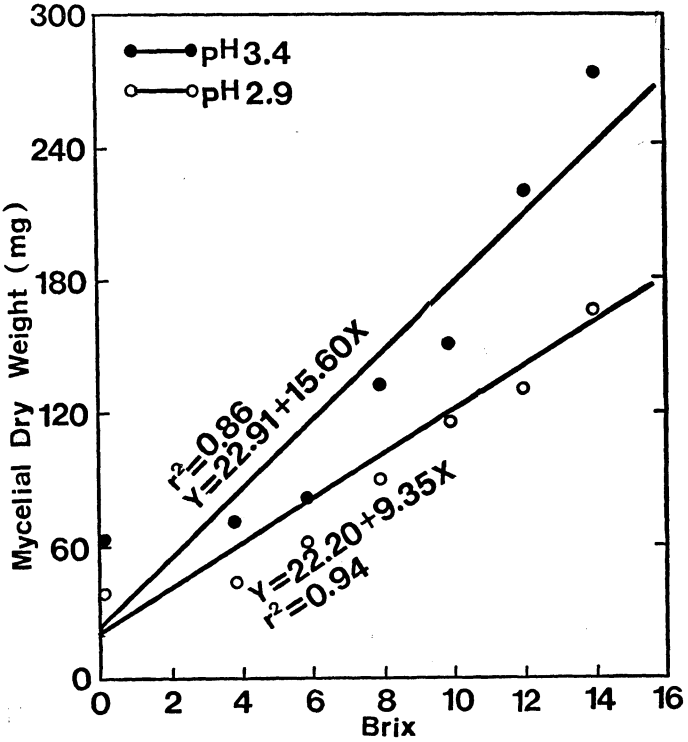
Table 2. Effect of grape juice extracted from different growing stages on the growth of *Colletotrichum gloeosporioides* causing ripe rot of grape

Time[a] (WK)	Grape juice		Mycelial dry weight[b] (mg)
	pH value	Brix	
6	2.93	3.8	93 c
5	2.96	4.1	99 c
4	3.12	11.1	1,130 b
3	3.32	13.2	1,604 a
2	3.44	13.9	1,582 a
1	3.56	16.7	1,617 a

[a]Weeks before harvest.
[b]Values followed by the same letter are not significantly different according to Duncan's multiple range test, P=0.01.

六、不同酸鹼度與糖度對晚腐病菌生長的影響

晚腐病菌無論在酸鹼度為2.9或3.4時，其生長量均隨糖度（Brix）的提高而增加。糖度與病菌生長量呈直線相關（P=0.01）（圖三）。



圖三、糖度及酸鹼度對葡萄晚腐病菌菌絲生長的影響

Fig. 3. Effect of total soluble solids(Brix) and pH value on the mycelial growth of *Colletotrichum gloeosporioides* causing ripe rot of grape.

討　論

由炭疽病菌（*Colletotrichum* spp.）所引起的作物病害，以分生孢子（conidia）爲主要的感染源[18]。病原菌藉分生孢子傳播到寄主植物的表面。在水膜上，分生孢子可迅速發芽並形成附著器（appressorium），再自附著器上產生侵入釘（penetration peg），侵入植物組織中[14]。但有許多作物的炭疽病菌於形成附著器或侵入釘後即停止生長[10]。此種雖已感染，但暫未表現病徵；最後，又再出現病徵的現象是爲潛伏感染（latent infection）[3]。葡萄晚腐病菌之不同菌株可在各個生長期的葡萄果皮上發芽並形成附著器。並於接種後 3 至 5 天，即產生黑褐色的病斑，這些病斑在果皮上逐漸擴大，並無停止之現象。將這些帶有病斑的表皮切成1mm^2 的小塊進行分離，可在75%的片段數上獲得晚腐病菌（筆者未發表資料），可證葡萄晚腐病之發病情形與潛伏感染的定義並不符合。至於人工接種之未發病幼果，至後期因可能受同果房已發病果之感染及滯留果皮上之原接種孢子發芽侵入，以是難以判斷是否有潛伏感染之現象。但如能作完整之切片觀察，則應有助於其感染現象之了解。由於潛伏感染是一錯綜複雜的現象，以筆者在本試驗中所用之有限菌株是否足以代表所有葡萄晚腐病菌之感染過程，及人工接種與自然感染之差異，均可能導致試驗結果之不同，此則有待設計更精確的試驗以證明之。

呂氏等[1]曾以組織學的方法探討晚腐病菌感染成熟葡萄果實的過程，但在幼果上的情形，則未說明。我們曾以組織切片的方法獲知晚腐病菌接種葡萄幼果後，經過三週，可見其果皮下除有菌絲之生長外並產生了少量的分生孢子；俟果實成熟時，則能產生大量的分生孢子。由此現象可以推斷，晚腐病菌感染葡萄不同生長期果實的過程，並無二致，僅有病勢進展速度之差異。Daykin 等[7]以人工接種的方法認爲葡萄晚腐病爲潛伏感染，我們與此項結果互異，是由於接種病菌病原性之差異，抑爲葡萄品種之不同所造成，則無法證實。但筆者確於田間發現葡萄幼果受到晚腐病菌自然感染而呈現病徵，然爲數不多。我們推斷，在本省的葡萄栽培條件下，晚腐病應可於果實各生長期發生，但不同生長期果實罹病後的發病速度則有不同。幼果期發病率偏低的原因，可能是幼果對晚腐病菌的抗性較高及田間接種源密度（inoculum density）較低的緣故。

葡萄果實在逐漸成熟的時候，以葡萄糖（glucose）爲主的碳水化合物（佔全果重15～25%）快速增加，同時有機酸含量（佔全果重0.3～1.5%）則逐漸降低[19]。由於上述兩類主要成分的消長，顯著影響病原菌的生長，已經本研究證實。此應可說明晚腐病在果實成熟期猖獗發生的原因。由於本病在果實成熟期由感染至形成次生感染源（secondary inoculum）僅需 7 至10天[1]，大量分生孢子再行感染，以致短期內病害發生非常嚴重。反之，在幼果期，雖可表現病徵，但由於病菌生長緩慢，且產孢稀少，以致無法在田間建立足量的接種源，病害亦因之非常少見。雖然糖度及酸鹼度之變化與病菌的生長有密切的關係；但因病原菌在自然培養基生長量的變化與人工培養基中生長量的增加率並未完全契合，亦即單以糖類及有機酸含量之變化尚難據以說明在果實成熟時，病原菌快速生長之全部原因。因此，病原菌在成熟的葡萄組織內快速生長的原因，可能尚包含其他成分之改變。

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Pathogenicity of *Glomerella cingulata* on Kyoho Grape

Chung-hang Duan[2] and Wen-hsui Hsieh[3]

Summary

Ripe rot of grape caused by *Glomerella cingulata* is a prevalent grape disease in Taiwan. Pathogenicity of the fungus in relation to the maturity of grape berry is tested in this study. By artificial inoculation in the field with conidia of the pathogen, necrotic symptom developed on all tested grape berries despite of the different maturity stages. However, different successive symptom progress was noticed on the grape berry with various maturity stagess. Generally, the more mature the grape berries, the faster the necrotic symptom would develop. It is also oberserved that the growth of the pathogen in young berries was only slower, but never cease, than that in the mature berries. Coordinating with the decrease of organic acids (pH value from 2.93 up to 3.56), the sharp increase of the total soluble solids (Degrees Brix from 3.8 up to 16.7) may be the major factors which influence the pathogen growth and the symptom development.
Key words: grape, pathogenicity, latent infection, *Glomerella cingulata*

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Mass Production of Phytoseiids :

I. Evaluation on Eight Host Plants for the Mass-rearing of *Tetranychus urticae* Koch and *T. kanzawai* Kishida (Acarina: Tetranychidae)[1]

Wen-Tai Lee, Chyi-Chen Ho and Kang-Chen Lo[2]

Abstracts : Ten crops were evaluated for mass-production of *Tetranychus urticae* Koch and *T. kanzawai* Kishida. Considering the cost of seeds, growth vigor of host plants, and reproduction rate of the spider mites, a soybean native variety, Chin-pe Tou, was the best. The rice seedling-nursery box (60×30×3cm) was chosen to maximize a continuous canopy produced under the least space with the lowest cost. The leaf weight, leaf area and plant height at various cultivating density were compared, and the density of 900 seedlings per box was considered the most economical. This method is suggested as the best method for mass-propagating spider mites so far. Information on the control of the various soybean pests was also given.

Introduction

Biological control of spider mites has been one of the major interest of acarologists in recent years. Among the various natural enemies of spider mites, the predaceous phytoseiids attracted the most attention. Phytoseiids were reported to be the predator of spider mites as early as in 1912 (Quale, 1912). Yet, their applicability was not studied until 1950's. Form then on, many authors studied the production and application of phytoseiids to control spider mites (Kamburov, 1966; McMurtry and Scriven, 1965, 1966 b, 1975; and Ristich 1956). However, these efforts to produce phytoseiids were primarily for small scale releases. The large scale releases were initiated only in the last 10 years (Fournier et al., 1985; Hendrickson, 1980; Hoy et al., 1982; and Storozhrov and Kaznacheeva, 1980).

Artifical diet has been studied for raising tetranychids (Fritzsche, 1960; Rodriguez and Davis, 1971; Storms and Noordink, 1970) and phytoseiids (Kennett and Hamai, 1980; McMurtry and Scriven, 1962, 1966a; Ochieng et al., 1987; Shehata and Weismann, 1972). None of these was proven to be promissing for mass production programs. Therefore, the most effective way of mass-producing phytoseiids is utilizing spider

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mites reared on host plants. Various host plants have been used to raise spider mites. The propagation of spider mites varied among host plants (Finney, 1953; Gerson and Aronowitz, 1980) and among varieties of the same host plant (Ashihare et al., 1986). The authors studied sweet potato, corn, water convolvulus, Mexican ageratum, clover and a few other crops in preliminary tests. Clover grew poorly under the hot climate of Taiwan and its leaf was too small to handle. The other crops were not as good as leguminous crops. This study compared ten leguminous crops and presents an economical and efficient method to grow a thick canopy to raise spider mites.

Materials and Methods

Crops characterized by their fast growing were selected for this study. After preliminary test, 10 crops of Leguminosae were chosen for comparing their suitability in raising spider mites, *Tetranychus kanzawai* Kishida and *T. urticae* Koch. These leguminous crops are:

Soybean	*Glycine max* L.
Chin-pe Tou	*Glycine max* L.
Hay Tou	*Glycine max* L.
Dutch case-knife bean	*Phaseolus coccineus* L.
Limabean	*P. limensis* Macf.
Snapbean	*P. vulgaris* L.
Pea	*Pisum sativum* L.
Sesbania	*Sesbania sesban* Merr.
Mungbean	*Vigna angularis* (Willd.) Ohwi et Ohashi
Adzukibean	*V. radiata* (L.) R. Wilcz.

The developing stages of the test crops were described following the system of Fehr et al. (1971), using V1, V2, and V3 to record the complete unroll of the primary leaf, the first trifoliate leaf, and the second trifoliate leaf, respectively.

Cost of Seeds

The averaged prices of seeds of the test crops were obtained through surveys of 3 stores in central Taiwan. As the sizes of seeds varied greatly among crops, this price was not the true cost of seeds. Therefore, a cost index (seeds per NT dollar) was calculated following the formula:

Cost index=1000 (gm)/seed wt. (gm)/price (NT/kg seeds.)

The seed weight was averaged from 10 measures of 100 seeds.

The Propagation rate of Spider Mites on the Host Plants.

A. Test 1.

Six, crops including soybean, Chin-pe Tou, Dutch case-knife bean, limabean, snapbean, and pea, were planted in October 1985. These crops were grown in 10×10cm pots. Each pot contained 2 seedlings of the same crop, and 5 replicates were made. These pots were kept in screen house. Ten adult females of *T. kanzawai* or *T. urticae* were introduced onto each plant at the V1 stage. The number of spider mites on each plant was counted 14 days after the introductions. The temperature ranged 19.5—31.3C and

relative humidity ranged 65—100% during the experimental period. Crops selected from this test were compared with other crops in test 2.

B. Test 2.

Methods used in test 1 were adopted in this test, except only *T. urticae* was intro duced, and the test was conducted in a growth chamber under 28C, 70—90% R. H., and 14 : 10(L : D) photoperiod. Eight crops including soybean, Chin-pe Tou, Hay Tou, limabean, snapbean, sesbania, adzukibean, and mungbean were studied from January to March. 1987.

The Growth Vigro of Host Plants

The test crops were sowed in rice seedling-nursery boxes (60×30×3cm), 45 boxes for each crop, in a screen house. Coarse sand was used as cultivating material. Twenty seedlings were allowed to grow up in each box. The fresh leaf weight and leaf area were measured at V1, V2, and V3 stages. Ten plants were measured each time for each crop with 15 replications. This study was conducted twice, once in summer (July-August, 1987), and repeated in winter (December-January, 1987—1988). Leaf area was measured by a leaf area meter (LI-COR, LI-3000). Leaf weight was measured by a fine balance (Sauter, model 414).

The Cultivating Density of Host Plants in the Rice Seedling-Nursery Box

After selecting a right crop, the proper density to cultivate the crop was tested. Chin-pe Tou, the selected crop, was grown in the rice seedling-nursery box same as the aforementioned test at the densities of 100, 200, 300, 400, 500, 600, 700, 800, and 900 seedlings per box, with 8 replications. Leaf area, leaf weight, and plant height were measured as in the growth vigor test. Twenty plants were sampled randomly each time from each box, and measured individually.

Results

Cost of Seeds

The seeds are sold in the unit of kilogram. Yet the sizes of seeds varied greatly

Table 1. The costs of seeds of the test crops

Crops	Price (N.T.$/kg) (a)	Wt./100 seeds (gm) (b)	Cost index* (Seed/N.T.$)
Soybean	46.7	12.79	167.40
Chin-pe Tou	46.7	6.22	343.99
Hay Tou	46.7	17.54	122.07
Dutch case-knife bean	166.7	43.96	13.65
Limabean	601.3**	166.31	1.00
Snapbean	666.7	13.36	11.23
Pea	166.7	16.96	35.38
Sesbania	60.0	1.79	929.23
Mungbean	33.3	6.04	497.38
Adzukibean	36.7	14.78	184.39

*Cost index=1,000/(b/100)/a
**One NT dollar/seed

among crops. For example, a limabean seed weighted ca. 93 times of a sesbania seed. Hence, the number of seeds purchased per NT dollar was calculated in Table 1 to compare the true cost of seeds. Limabean was most expensive, followed by snapbean, Dutch case-knife bean, pea, Hay Tou, soybean, adzukibean, Chin-pe Tou, and mungbean. Sesbania was the cheapest.

The Propagation rate of Spider Mites on the Host Plnt

The results of Test 1 were shown in Table 2. Among the 6 tested crops, pea was a good food source for *T. urticae*, but was poor for *T. kanzawai*. Limabean and snapbean which were most commonly used by other researchers gave poor results both for *T. urticae* and *T. kanzawai*. Chin-pe Tou, Dutch case-knife bean, and soybean gave high performance for the growth of both spider mite species. Production of the spider mites by these 3 crops were 5 to 10 folds of the other crops. Therefore, these 3 crops were selected and tested again in Test 2. Snapbean was included for its large leaf size and smooth leaf surface.

Table 2. *Tetranychus urtiae* and *T. kanzawai* raised from six crops*

Crops	*T. kanzawai*			*T. urtiae*		
	Egg	Adult + Young	Total *	Egg	Adult + Young	Total *
Chin-pe Tou	2,571	357	2,928a	2,587	313	2,900a
Duth case-knife bean	1,816	786	2,602a	1,109	1,137	2,246ab
Soybean	1,176	1,658	3,134a	1,117	948	2,065ab
Pea	268	272	540b	1,141	384	1,525b
Snapbean	535	104	639b	199	34	233c
Limabean	154	72	226b	126	54	180c

*Mean from 10 plants at the 14th day after the introduction of spider mites. Means followed by the same letter are not significantly different at 5% level by Duncan's multiple range test.

The results of Test 2 were give in Table 3. Among the test crops sesbania produced the highest number of *T. urticae*. Soybean and Chin-pe Tou produced high number of *T. urticae* and showed conisstently good results. Dutch case-knife bean was the worst for propagating spider mites, while the others were in the middle.

Table 3. *T. urtiae* raised on 8 crops under 28C, 70—90% R. H. in growth chamber

Crops	*T. urtiae*		
	Egg	Adult+Young	Total *
Sesbania	1,478	496	1,974a
Soybean	1,539	390	1,929ab
Chin-pe Tou	1,374	317	1,691abc
Hay Tou	781	464	1,245bc
Mungbean	989	286	1,275bc
Snapbean	911	239	1,129cd
Adzukibean	747	231	978cd
Dutch case-knife bean	254	43	297d

*Mean from 10 plants at the 14th day after the introduction of spider mites. Means followed by the same letter are not significantly different at 5% level by Duncan's multiple range test.

The Growth Vigor of Host Plants

The growth vigor studies were conducted both in summer and winter, because the host plant should be grown year-round. Limabean was discarded early in this study because of its poor performance in the rice seedling-nursery box. Pea was also excluded from the test due to poor and uneven germination.

Under the testing conditions, mungbean stopped growing at V2 stage. Snapbean grew normally in summer, but stopped growing at V2 stage in winter. The other crops grew normally. Hay Tou was out of supply in the winter time, therefore, it was not tested in winter. The results of this study were listed in Table 4 (summer) and Table 5 (witer).

Table 4. Leaf weight (gm/plant) and leaf area (cm^2/plant) of 8 crops at 3 developmental stages* cultivated in the rice seedling-nursery box in summer (July-August, 1986)

Crops	Leaf wcight			Leaf Area		
	V1	V2	V3	V1	V2	V3
Soybean	0.267	0.623	1.255	15.289	36.672	69.317
Chin-pe Tou	0.133	0.308	0.601	8.749	20.442	37.034
Hay Tou	0.261	0.683	1.087	14.933	39.341	61.445
Dutch case-knife bean	1.149	2.511	3.121	36.973	79.694	102.412
Snapbean	0.551	1.373	2.391	23.233	50.876	75.224
Sesbania	0.025	0.080	0.135	1.349	4.092	7.333
Mungbean	0.181	0.421	—	8.496	15.099	—
Adzukibean	0.210	0.571	0.652	8.042	25.673	29.024

* V1 : complete unroll of the primary leaf.
V2 : complete unroll of the 1st trifoliate leaf.
V3 : complete unroll of the 2nd trifoliate leaf.

Table 5. Leaf weight (gm/plant) and leaf area (cm^2/plant) of 7 crops at 3 developmental stages* cultivated in the rice seedling-nursery box in winter (December-January, 1986—1987).

Crops	Leaf weight			Leaf Area		
	V1	V2	V3	V1	V2	V3
Soybean	0.308	0.554	0.884	16.858	31.941	47.161
Chin-pe Tou	0.187	0.412	0.665	11.052	20.640	36.383
Dutch case-knife bean	1.688	2.943	3.479	61.414	98.425	122.740
Snapbean	0.476	1.331	—	13.254	49.215	—
Sesbania	0.014	0.030	0.053	0.701	1.945	2.618
Mungbean	0.203	0.395	—	8.831	14.854	—
Adzukibean	0.193	0.493	0.606	9.835	21.659	24.280

*V1 : complete unroll of the primary leaf.
V2 : complete unroll of the 1st trifoliate leaf.
V3 : complete unroll of the 2nd trifoliate leaf.

The growth period of the test crops in winter took twice as long as in summer. The leaf weight and leaf area of the crops grown in the winter were generally less than those grown in the summer. Dutch case-knife bean and Chin-pe Tou were the exceptions, which grew better in the winter. Generally, the larger seed produced a plant with a greater leaf area and heavier leaf weight, with one exception of adzukibean. Accordingly, no statistic analysis was carried on these data. Instead of, these data and the cost index in Table 1 were calculated for the leaf weight and leaf area produced per NT dollar, and the results were drawn in Figures 1, 2, 3, and 4. Among the

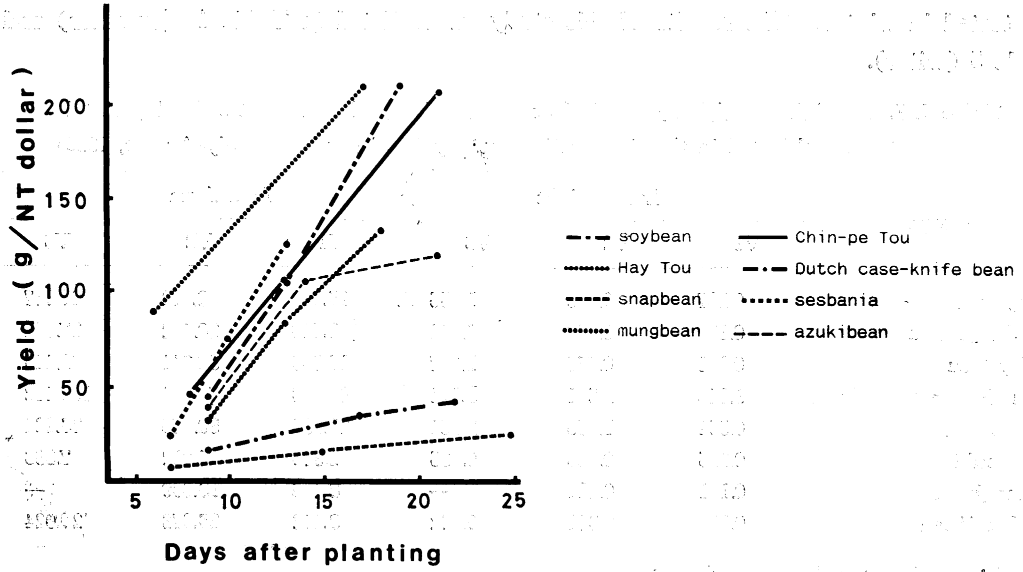

Figure 1. Leaf weight of various crops produced per NT dollar in summer (July -August, 1986)

three test crops, Chin-pe Tou yielded the largest leaf area and the heaviest weight per unit cost both in summer and winter. Mungbean was comparable to Chin-pe Tou for leaf weight but not for leaf area. Soybean grew well in summer but not in winter.

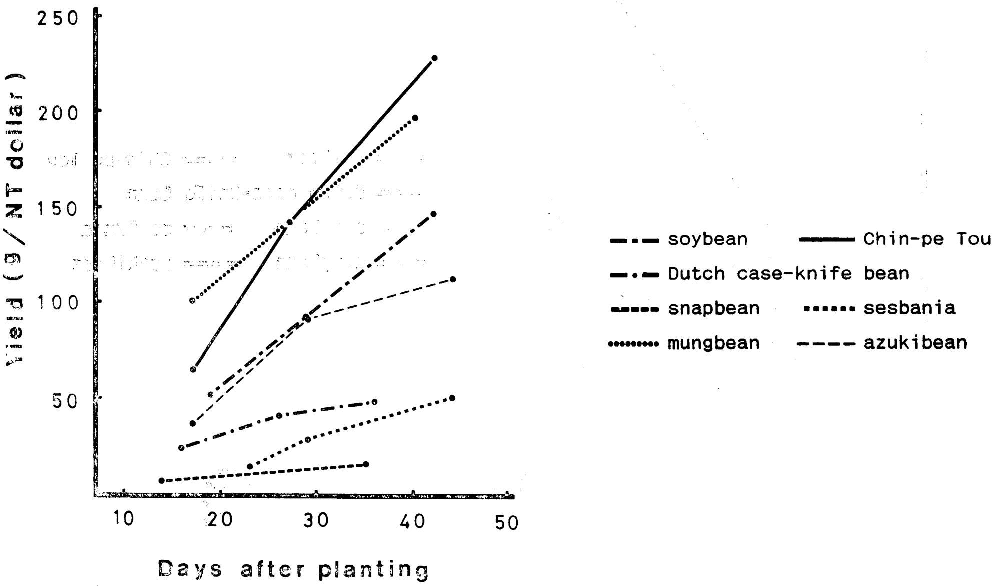

Figure 2. Leaf weight of various crops produced per NT dollar in winter (December-January, 1986—1987)

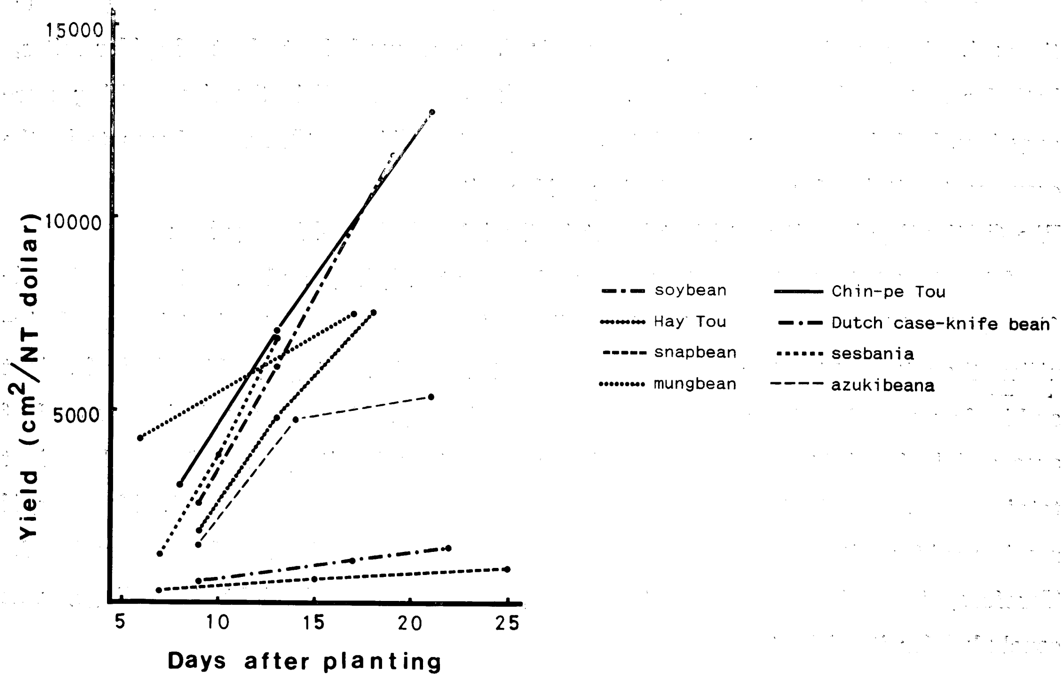

Figure 3. Leaf area of various crops produced per NT dollar in summer (July-August, 1986)

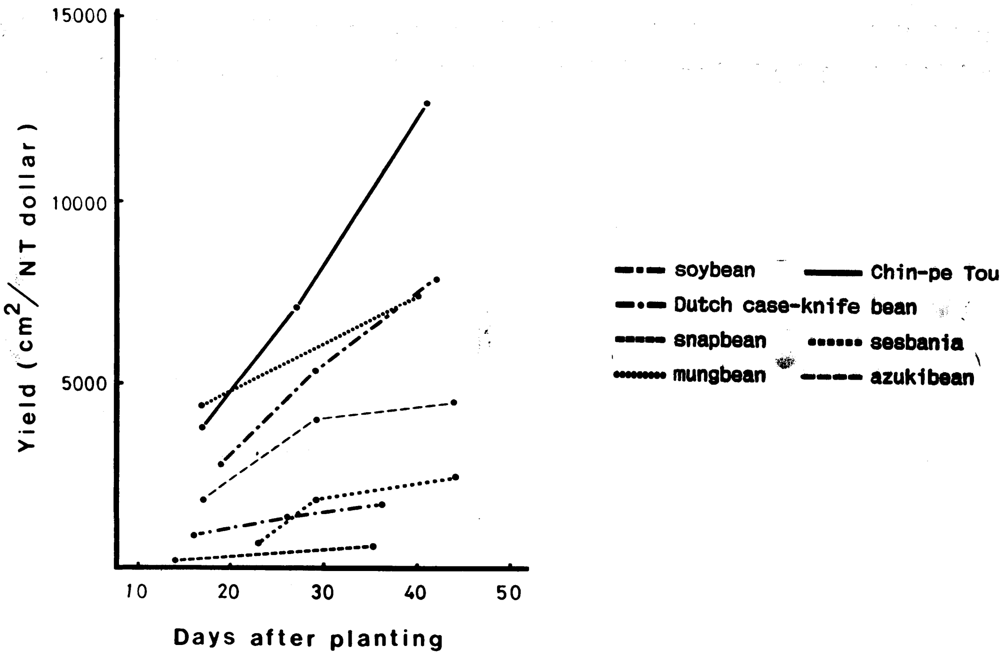

Figure 4. Leaf area of various crops produced per NT dollar in winter (December-January, 1986—1987)

Based on the studies above, only Chin-pe Tou fulfilled all of the following conditions: 1. Cheap and available year-round; 2. Be a good host plant of spider mites, both for *Tetranychus urticae* and *T. kanzawai*; 3. Grown well in the rice seedling nursery box, both in summer and winter. Consequently, Chin-pe Tou was chosen to be the crop most suitable for mass-producing spider mites.

The Cultivating Density of Host Plant in the Rice Seedling-Nursery Box

The plant height, leaf weight and leaf area at V1, V2, and V3 stages under different densities were shown in Figure 5 and Table 6. The plant height increased significantly with cultivating density especially at V2 and V3 stages, while the leaf weight and leaf area produced per plant decreased significantly. Although the difference on leaf area and leaf weight was not large, higher cultivating density produced more luxuriant total canopy. The high-grown plant is easy to be blown down by wind. However, if rearing spider mites in a glass house or a screen house, such hazard can be reduced. Terefore, 900 Chin-pe Tou plants per box, though produced hightest seedlings, was concluded for its richest canoy.

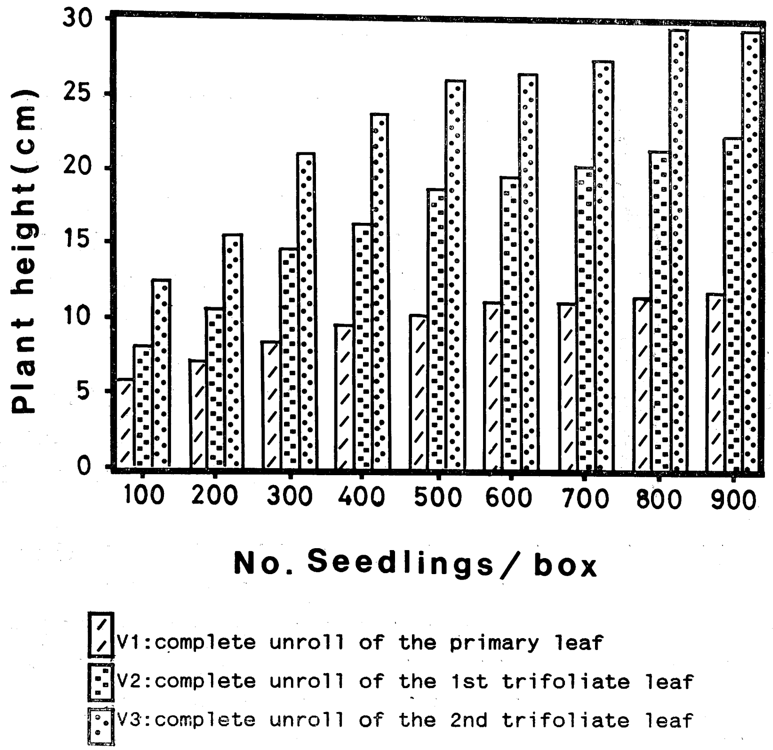

Figure 5. Height of Chin-pe Tou at 3 developing stages under various cultivating densities.

Table 6. Leaf weight (gm/plant) and leaf area (cm^2) of Chin-pe Tou at 3 developing stages* under various cultivating densities.

Density (seedling/box)	Leaf weight			Leaf Area		
	V1	V2	V3	V1	V2	V3
100	16.68	36.55	60.45	1.203	2.681	4.569
200	33.69	74.18	115.40	2.399	5.495	8.670
300	45.35	105.66	177.72	3.366	8.042	13.235
400	63.87	139.68	231.36	4.894	10.823	16.847
500	70.83	173.15	261.65	5.337	12.938	20.411
600	84.14	201.90	322.98	6.459	15.247	23.509
700	91.73	238.21	359.11	7.276	18.204	27.520
800	103.80	260.32	426.48	8.332	20.214	32.615
900	117.03	298.26	457.56	9.267	22.916	35.442

*V1 : complete unroll of the primary leaf.
V2 : complete unroll of the 1st trifoliate leaf.
V3 : complete unroll of the 2nd trifoliate leaf.

Discussion

The price of seed varied with season and region. A seed with a steady price is usually supplied steadily. Chin-pe Tou is available year-round and its price is quite stable. This a very important advantage for a mass-rearing program and played an important role while the authors made decision on the most suitable host plant.

Ashihara et al. (1986) compared the ovipostion of *T. urticae* on 4 varieties of kidney bean (=snapbean of this study) and 2 varieties of soybean. They concluded that the former is better because kidney bean grew faster and had greater leaf area than soy bean, and spider mites oviposited more eggs on kidney bean. In our studies, soybean grew faster than snapbean both in summer and winter, and both *T. urticae* and *T. kanzawai* had higher reproductive rates when feed on soybean than on snapbean. This may be due to the difference in the variety tested and, especially, the difference in the cultivating method.

Crops for raising spider mites can be cultivated in fields, pots, bag, or shallow pans. Most researches grew crops in fields or pots, and exposed them to spider mites at the later stage of crop development. This had the advantages of labor saving and providing more leaf surface for raising spider mites. However, growing crops in fields or pots has a greater risk to be invaded by other insects and mites, phytophagous or predaceous, which would interfere the mass-production effort (Finney 1953, Scriven and McMurtry 1971).

Scriven and McMurtry (1971) reduced the possibility of the establishment of mite predators and phytophagous insects on the crops by rapid turnover of plants. We found that the rice seedling-nursery box was ideal for cultivating the crops, because: 1. It can sustain the growth of many crops up to V4 stage, which is long enough for rearing phytoseiids. 2. Only a small amount of sand or cultivating material is required because of the shallowness of the box. Consequently, it is not heavy and easy to handle. 3. As there is less vacuity between the boxes, it is space-saving when compared with the round-shaped pot. 4. It is a marketed product, and is, therefore, cheap and readily available.

Scriven and McMurtry (1971) grew 100 plants in a 18×24×2 in (ca 0.28m^2) tray, and produced 1.29g of *Pacificus* (ca. 353,860 individuals of all stages). Storozhkov and Kaznacheeva (1980) reported the production of 174,400 phytosiids per m^2 per season in glass house. The rice seedling-nursery box was measured 0.18m^2. An estimation of over 1,000,000 spider mites or 15,000 phytoseiids of all stages could be reared each time from each box. This was considerably higher than those found in other reoports. This method is, therefore, suggested as the best method for mass-propagating spider mites so far.

There were a few diseases and insect pests attacking Chin-pe Tou during growing periods. These pests were controlled by using chemical and mechanical method. The major pathogens, *Pythium* spp. and *Rizoctonia* spp. were controlled by 1. Dipping seeds in either the 2000x dilution of Etridiazole 35% W. P. or the 1500x dilution of Iprodione 50% W. P. for two hours; or 2. Mixing each kilogram seeds with any of the fungicides

below: 2g of Thiram 65% W. P., 4g of Chlorothalonil 75% W. P., or 2g of Etridiazole 35% W. P., Lepidopteran pests, such as Tobaccoo cutworm, leaf roller, and tussock moth, were controlled by 2000x dilution of Methomyl 90% W. P. The best way to control lepidopteran pests was to keep the plants free from the infestation of moths by growing them inside screen house. Aphids could be controlled with the 20000x dilution of Pirimicarb 50% W. P. which showed no negative effect on the growth of spider mites.

Acknowledgements

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捕植蟎之大量繁殖

I 葉蟎飼育植物之選擇[1]

李文台 何琦琛 羅幹成[2]

摘　要

以水稻育苗箱爲栽種器材，測試比較種子購買成本，植物生長速率及葉蟎繁殖速率等三項因素，自10種豆科植物中選出本地土生品系之青皮豆爲大量繁殖捕植蟎所需之葉蟎飼育用植物。爾後測量葉面積、葉重及株高三項性狀，選擇每育苗箱種植 900株青皮豆爲最佳種植密度。如此，可在最小之空間上以最低之生產成本，全年持續不斷地生產最大量之葉蟎飼育植物，做爲大量繁殖捕植蟎之基礎。

1.臺灣省農業試驗所 研究報告第 1511 號。

2.本所應用動物系助理研究員、副研究員、研究員兼系主任。臺灣省 臺中縣 霧峰鄉。

中華農業研究（Jour. Agric. Res. China）39(2)：133～140（1990）

利用法拉斯捕植蟎及智利捕植蟎防治茶神澤氏葉蟎之探討[1]

何　琦　琛[2]

摘要：溫室盆栽臺茶13號茶苗以神澤氏葉蟎：捕植蟎＝20：1 之比例接種法拉斯捕植蟎或智利捕植蟎，接種法拉斯捕植蟎之處理在接種後第10天及第14天分別達到72.8%及88.6%之防治率，而接種智利捕植蟎之處理則有84.0%及99.1%之防治率，田間在青心烏龍茶園釋放此 2 種捕植蟎，均對神澤氏葉蟎有良好之抑制效果，尤其智利捕植蟎之效果更爲迅速。而田間自然發生之溫氏捕植蟎其功效似遜於此 2 種捕植蟎。

神澤氏葉葉蟎（*Tetranychus kanzawai* Kishida）自民國67年首先在梨山地區茶園發現後，2、3 年間在全省大多數茶園皆可見其蹤跡，逐漸取代茶葉蟎（*Oligonychus coffeae*（Nietner））而成爲臺灣茶園之主要害蟎（陳，1986；廖，1985）。茶葉蟎主要爲害中、老葉片，較少爲害嫩葉，對製茶之影響較小。神澤氏葉蟎則亦爲害嫩葉，被害茶菁所製之茶具有異味，風味差，市場價值大爲滑落，而其發生季節多在春季及秋、冬季，適爲茶菁品質最佳，售價最高之時期，對茶農收益影響至鉅。因此茶農依賴施用農藥防治此一大害蟎，由於葉蟎之體積小、繁殖快，每季茶可能需施藥 2 － 3 次方能予以有效壓制。神澤氏葉蟎已有對農藥產生抗性之報告（刑部，1987；Ohtani, 1988; Osakabe, 1974），鹿谷地區茶農亦屢屢反應施用殺蟎劑防治此葉蟎效果不彰。此外，茶爲消費者每日之飲料，嗜好者消耗量甚高，農藥殘毒之顧慮極大，殺蟎劑爲極可能殘存於茶葉中之農藥。智利捕植蟎（*Phytoseiulus persimilis* Athias-Henriot）及法拉斯捕植蟎（*Amblyseius fallacis*（Garman）均被利用以防治葉蟎，且成效卓著（Helle and Sabelis, 1985; McMurtry, 1982）。本所自美國引進此 2 種捕植蟎，防治草莓及桑樹上之葉蟎，效果良好。本文爲利用此 2 種捕植蟎防治茶園神澤氏葉蟎之初步研究結果。

材料與方法

一、溫室試驗：

民國78年 1 月在玻璃溫室中以盆栽一年之臺茶13號茶苗接種神澤氏葉蟎，所接種之葉蟎係採自阿里山茶區，在室內以青皮豆苗繁殖達半年以上者。接種葉蟎 3 天後，葉蟎已定著良好，每盆逢機選取 5 葉片，目視計算葉蟎之數目及各盆茶苗之葉片數。以之分別計算各盆之葉蟎數，而後各盆接種葉蟎數量 1 ／20之捕植蟎。法拉斯捕植蟎及智利捕植蟎各接種10盆，加對照組共30盆茶苗，此後於第 3 、 7 、10、14天觀察各盆茶苗上葉蟎之數目，方法與釋放捕植蟎前相同，此外，釋放智利捕植蟎組在第

1.臺灣省農業試驗所　研究報告第1512號。本研究承行政院農業委員會（78農建—7.1—65（12））計畫補助經費，特此致謝。
2.臺灣省農業試驗所應用動物系副研究員。臺灣省　臺中縣　霧峰鄉。

10天、釋放法拉斯捕植蟎組在第14天各於每盆採取10片葉片，攜回實驗室在雙筒立體顯微鏡下計數葉蟎及捕植蟎之數目。

二、田間試驗：

民國77—78年冬季在松柏坑茶區進行，試驗茶園約 2 分地，爲一長條形茶園，植有 7 行青心烏龍。

（一）試驗 1：

於此茶園設立 3 試驗小區，分別爲釋放法拉斯捕植蟎、智利捕植蟎區及未釋放之對照區。小區包含 4 行茶，每行10叢。77年12月13日釋放法拉斯捕植蟎 25,000隻，78年 1 月12日釋放智利捕植蟎60,000隻。釋放前及釋放後每星期調查 1 次，對照區自 1 月 5 日起調查。至 3 月16日茶農開始爲春茶施藥始停止調查。調查時每小區各逢機取樣 100 片葉片及30枝長約10公分之小枝梢（約生長有 5 片葉片），攜回實驗室以立體顯微鏡檢察葉蟎及捕植蟎之數目，並鑑定捕植蟎之種類。

（二）試驗 2：

除前述小區試驗外，又另選 5 茶叢於 1 月30日及 2 月 9 日分別各釋放智利捕植蟎 5,000隻，調查方法與試驗 1 相似，但僅調查50葉片上之葉蟎及捕植蟎之數目。

結果與討論

一、溫室試驗：

溫室試驗之結果整理如表 1。釋放前各處理組茶苗上神澤氏葉蟎之族羣密度無顯著差異，各盆苗上之葉片數在14至53片間，數量不多，是以調查時並未採摘葉片鏡檢，而以目視檢查葉片。釋放後第10天及第14天釋放智利捕植蟎組及法拉斯捕植蟎組之葉蟎密度分別降至每葉片 3 隻多，乃另採摘10葉片攜回實驗室在立體顯微鏡下計數葉蟎及捕植蟎之數目，所得結果與目視檢查幾乎相同，可證本實驗目視檢查結果之正確性。表 1 顯示以葉蟎數量 1／20之比例釋放捕植蟎，釋放法拉斯捕植蟎後第10天已可達成70%之防治率，迄第14天防治率已達88.6%。釋放智利捕植蟎之效果更好，在第10天即達成84%之防治率，第14天更達成99%之防治率。由於缺乏食物，智利捕植蟎開始遷散，是故第14天時原釋放法拉斯捕植蟎茶苗上亦發現有智利捕植蟎。本試驗中，法拉斯捕植蟎及智利捕植蟎均表現出對茶

表1. 溫室中以法拉斯捕植蟎及智利捕植蟎防治茶苗上之神澤氏葉蟎之效果

Table 1. Control of *T. kanzawai* by *A. fallacis* and *P. persimilis* in potted tea plants in glasshouse.

處理		釋放前	釋放後			
			第 3 天	第 7 天	第10天	第14天
AF	TK	29.1a	15.2ab	11.4 b	6.5 b	3.7 b(3.56+1.69)
	AF		0.58	1.14	0.96	1.68 (1.37+0.04)
防治率 (%)			24.3	36.2	72.8	88.6
PP	TK	25.1a	11.1a	8.5 b	3.3b (2.46+1.52)	0.2 b
	PP		0.62	1.44	1.68(1.4+0.64)	0.48
防治率 (%)			36.0	45.6	84.0	99.1
CK	TK	29.8a	20.6b	18.4 a	24.6 a	33.4 a

1.表中數字爲 5 片葉片上之平均成蟎加幼、若蟎數，括弧中爲顯微鏡鏡檢10片葉片之平均成、若、幼蟎數＋卵數。
2.AF、PP、TK、CK 分別代表 *A. fallacis*、*P. persimilis*、*T. kanzawai*、Check.
3.直排同排數字尾標以相同英文字母者在 Duncan's multiple range test 中0.05水準下差異不顯著。

樹上之神澤氏葉蟎具有極佳之防治能力。

二、田間試驗：

臺灣中部在南投縣之茶園，均以化學藥劑防治葉蟎，而近年來國內茶價甚好，故產茶季節中極難尋找發生神澤氏葉蟎之茶園進行生物防治試驗。迄冬季休閒期間方始尋得1試驗茶園。試驗進行時，因捕植蟎供應調節之緣故，首先僅釋放法拉斯捕植蟎，一個月後方釋放智利捕植蟎。釋放前後，小區中澤神氏葉蟎密度消長列於表2.並將各小區中葉蟎及捕植蟎之密度消長繪於圖1。試驗茶園神澤葉蟎密度以智利捕植蟎區最高，在78年1月間達到平均每葉片30餘隻，每枝梢超過 100隻。對照區次之，每葉片達20餘隻，每枝梢達80餘隻。法拉斯捕植蟎區因在77年12月間即已釋放捕植蟎，葉蟎密度僅達

表2. 田間以法拉斯捕植蟎及智利捕植蟎防治茶園神澤氏葉蟎之效果（1988—1989）。

Table 2. Control of *T. kanzawai by A. fallacis* and *P. persimilis* on tea (1988-1989).

Date	Treatment					
	AF		PP		CK	
	A	B	A	B	A	B
12/13	1.28	25.83	—	—	—	—
12/20	1.14	29.67	—	—	—	—
12/28	2.86	21.24	—	—	—	—
1/5	2.58	56.60	—	—	12.65	86.37
1/12	5.91	54.50	31.47	119.03	9.77	69.27
1/19	7.28	43.04	22.21	70.86	16.84	66.70
1/26	6.89	15.53	10.44	68.77	23.28	80.83
2/2	5.11	10.67	2.61	15.23	19.46	48.00
2/9	4.43	15.90	2.67	7.20	25.61	35.33
2/16	1.52	7.87	2.25	8.04	7.66	31.40
2/23	5.52	2.83	3.62	26.60	22.22	66.20
3/3	2.56	2.36	0.12	4.80	23.39	52.97
3/10	0.89	2.77	0.09	0.30	16.22	53.57
3/16	0.10	2.30	0.02	0.06	4.38	9.33

表中數字爲神澤氏葉蟎數，A爲100葉片之平均葉蟎數，B爲30枝梢之平均葉蟎數。

AF、PP、CK 之解說參見表1.

每葉片 7 隻或每枝梢50餘隻。防治情形以釋放智利捕植蟎最優，釋放捕植蟎後不論以葉片或枝梢爲取樣單位，葉蟎密度都幾呈直線下降，在 3 星期中由每葉片31隻降至 2 隻左右；而同 1 時期對照區之葉蟎密度却持續上升中。但智利捕植蟎亦隨而遷散，是以葉蟎密度在每葉片 2 隻左右徘徊 4 星期後才降至每葉片 1 隻以下，釋放法拉斯捕植蟎之數量不及智利捕植蟎之數量，是以初期效果不彰。以枝梢計，3 星期後方始現出防治效果；以葉片計，則 5 星期才出現效果。釋放法拉斯捕植蟎區葉蟎密度劇降時對照區之葉蟎密度亦正下降，因而影響對其效果之判斷。

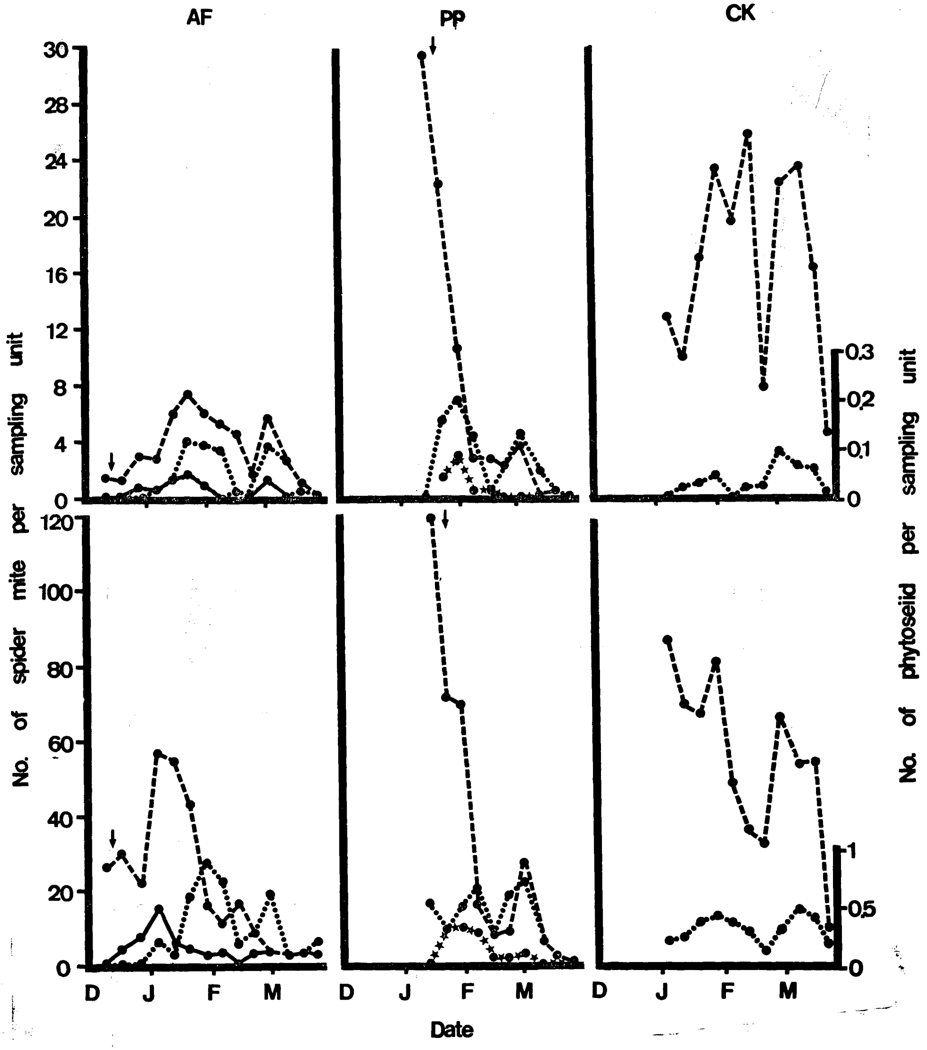

圖1. 釋放法拉斯捕植蟎及智利捕植蟎防治茶園之神澤氏葉蟎

Figure 1. Control of *T. kanzawai* on tea by releasing *A. fallacis* (AF) and *P. persimills* (PP). Upper graphs: sampled by leaves. Lower graphs: sampled by branch terminals.

---- T. kanzawai　　━━ A. fallacis
••••••• A. womersleyi　　★★★★ P. persimilis

第 2 次試驗釋放智利捕植蟎時，再得到與第 1 次試驗時相類似之效果，釋放後葉蟎密度即迅速下降（圖2）。

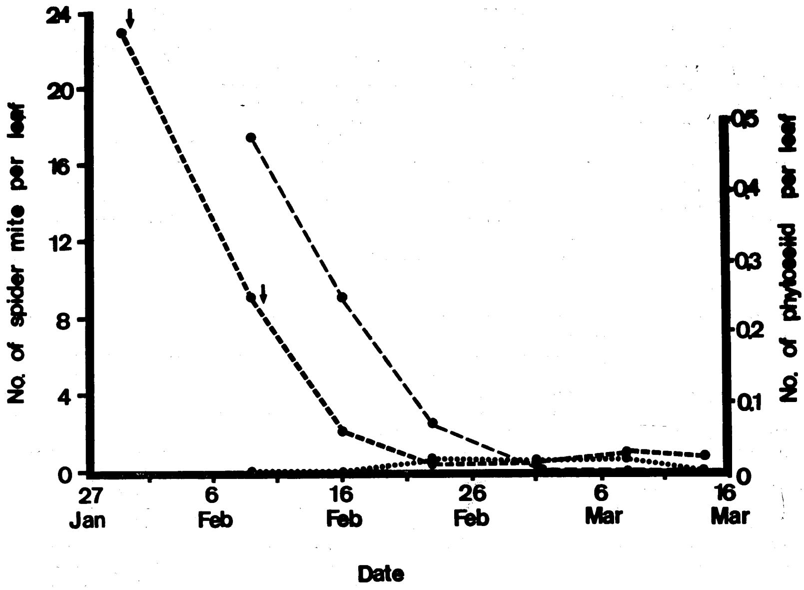

圖2. 釋放智利捕植蟎防治茶園神澤氏葉蟎（第2次測試）

Figure 2. Control of *T. kanzawai* qy *P. persimilis* (second trial).

---- T. Kanzawai ······· A. womersleyi
-·- P. persmilis

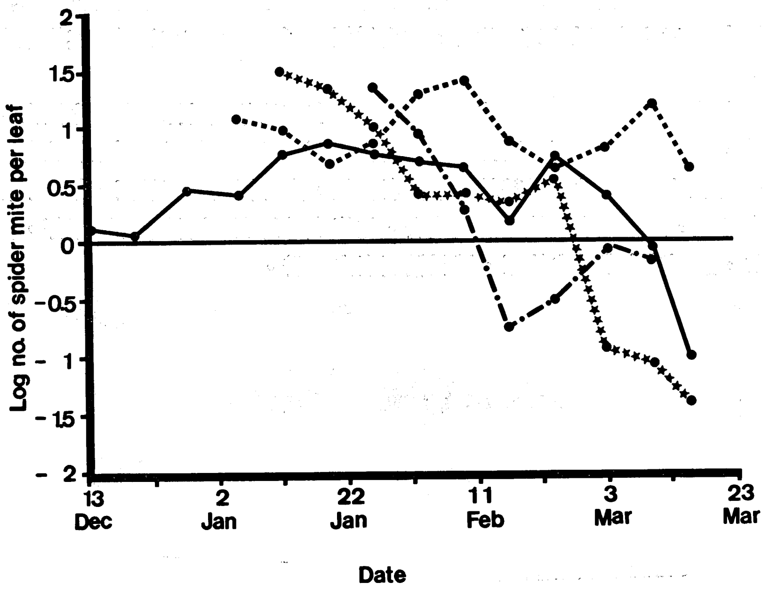

圖3. 不同處理間神澤氏葉蟎密度變化之比較

Figure 3. Population fluctuation of *T. kanzawai* at various treatments.

•••• CK
—— A. fallacis released
-*-* P. persmilis released
•—• P. persmilis released (trial 2)

綜合溫室盆栽茶苗試驗及田間試驗之結果，可確認智利捕植蟎對茶園之神澤氏葉蟎具有防治效果。法拉斯捕植蟎則雖亦有效，但其效果不如智利捕植蟎迅速。室內在茶上飼育法拉斯捕植蟎及智利捕植蟎發現此二種捕植蟎之產卵量皆受影響，較在豆上飼育少。尤以法拉斯捕植蟎受影響最爲明顯，產卵量減少甚多；但法拉斯捕植蟎可在第 2 代起逐漸適應（何，未發表資料）。此種情形或爲法拉斯捕植蟎在本田間試驗表現不如理想之部分原因。目前在茶園中神澤氏葉蟎之暫訂容許密度爲每葉片 1 隻（陳惠藏氏，私人通訊），將各小區之神澤氏葉蟎密度之對數值繪於圖3.釋放法拉斯捕植蟎及智利捕植蟎區均於 3 月降至每葉片 1 隻以下，對照組則不然。據此判斷，此 2 種捕植蟎均具有利用以防治茶園神澤氏葉蟎之潛力。

試驗茶園有自然存在之溫氏捕植蟎（*Amblyseius womersleyi*）族羣，密度常高於釋放之 2 種捕植蟎。其與葉蟎之密度消長，呈現出明顯之天敵與食餌關係。然而對照組同樣有溫氏捕植蟎，却未能壓抑神澤氏葉蟎族羣，顯示溫氏捕植蟎在試驗茶園中未能抑制神澤氏葉蟎之族羣；相同結果亦在圖 3 中顯示。但如前所言，溫氏捕植蟎明顯爲試驗茶園中之神澤氏葉蟎天敵，對其防治具有某種程度之貢獻（以圖 1 所示，可能在神澤氏葉蟎密度低時效果較好）。Hamamura (1986) 認爲在日本之茶園中以長毛捕植蟎（*A. longispinosus*）最具防治神澤氏葉蟎之潛力。臺灣以長毛捕植蟎防治草莓上之神澤氏葉蟎亦有很好之效果（羅等、1984）。陳（1987）以長毛捕植蟎防治茶園神澤氏葉蟎，其資料中神澤氏葉蟎密度甚低，不足彰顯長毛捕植蟎之效果。溫氏捕植蟎爲臺灣農作物上極常見之捕植蟎，與長毛捕植蟎極爲近似，1975年由 Schicha 分出爲獨立種 (Schicha, 1975). Collyer (1982) 比較彼在紐西蘭所採集之標本後，認爲二者爲同種。筆者以爲仍係 2 不同種。由本試驗資料顯示溫氏捕植蟎在茶園中適應良好、自然發生，雖然防治神澤氏葉蟎之功效不如智利捕植蟎及法拉斯捕植蟎，但筆者認爲綜合防治系統中不可僅利用 1 或 2 種天敵，應包含有多種天敵。以本研究之田間試驗而言，引進之捕植蟎將葉蟎密度壓低後，隨即散去，餘留之葉蟎仍需本地捕植蟎來看守。故茶園生態系中溫氏捕植蟎所能扮演之角色不應予以放棄。此外，如人爲促進（augmentation）其族羣密度，亦可能改善其防治效果。

綜合本研究之結果，智利捕植蟎及法拉斯捕植蟎具有防治茶園神澤氏葉蟎之潛力。臺灣年採茶 5 次以上，春、秋、冬三季茶有可能受神澤氏葉蟎爲害，而葉蟎爲害茶嫩葉對茶菁及所製出茶之品質有很大之影響，必需予以防治。此三季茶較受消費者喜愛，亦即經濟價值較高，茶農不吝施藥，因此也有殘留殺蟎劑之顧慮，對消費者之健康造成威脅。如能成功的利用捕植蟎保護茶芽，使茶農不因葉蟎爲害而蒙受損失，進而減少農藥之施用，將爲消費者之福音。

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A preliminary study on the biological control of *Tetranychus kanzawai* in tea field by *Amblyseius fallacis* and *Phytoseiulus persimilis* (Acarina: Tetranychidae, Phytoseiidae)[1]

Chyi-Chen Ho[2]

Summary

Amblyseius fallacis and *Phytoseiulus persimilis* were introduced to potted tea plants in glasshouse at a ratio of one twentyth of *Tetranychus kanzawai*. Both phytoseiid predators showed effective in the control of *T. kanzawai*. *Amblyseius fallacis* gave 72.8% and 88.6% of control at the 10th and 14th day after release, respectively, and, *P. persimilis* acchieved 84.0% and 99.1% of control. In field trials, release of both species, especially *P. persimilis*, reduced the population of *T. kanzawai* to less than one spider mite per leaf. A natural population of *A. womersleyi* in the experimental tea field contributed partially to the reduction of the population of spider mites, but it seemed could not suppress the spider mite population alone.

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中華農業研究（Jour. Agric. Res. China）39(2)：141～147（1990）

農試型落花生聯合收穫機之研製II[1]

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摘要：農試型落花生聯合收穫機之前處理部在加裝强制送株機構及輔助分株機構後，可穩定植株之夾持位置並突破徒長植株交纏積堵之瓶頸；排株機構因强制脫離與頂出機構之輔助，植株之排出作用確實而無回纏之弊。前集莢帶與裝袋機主動軸經改良後機構之負荷減輕，裝袋機無滑動現象，故送莢作業確實無夾裂之虞。本型收穫機之作業性能已因前述機構之修正與改良而更趨穩定，單位時間之有效工作能量亦因而大幅提高。

關鍵字：落花生、收穫機

農試型夾持式落花生聯合收穫機之研製工作，經上年度田間試驗與逐次改良結果，其收穫作業性能雖已符合原設計要求，作業品質亦已達到農民期望之水準以上，唯植株經扶起後飼株作業時因株條紛散，使得植株夾持位置不正確，致在脫莢過程中脫莢筒被植株纏繞，使引擎過負荷中斷作業而進行清除，造成脫莢效率降低，衍生脫莢不完全之嚴重殘留現像。同時前處理部位置之設定悉由人工爲之，致費時而影響田間作業能力。爲提高機構間作業穩定性、單位時間工作能力與作業精度，本設計尙需在機構上加以改良，方克突破目前之瓶頸，使本機之作業性能更實用化，並克服代耕中心業者觀望之心態而順利推廣，使本省落花生之收穫作業早日全面機械化。

爲解決農試型落花生聯合收穫機目前在作業中所衍生之缺點，針對機構設計技術上之瓶頸，重新規劃及改良相關機構之設計，使本型收穫機之作業穩定性及作業品質提高，提升該設計推廣潛力，使本省落花生栽培作業早日全面機械化，落實研究成果。

材料與方法

一、機構設計與改良

（一）飼株機構之研製

（二）自動位置檢出機構之設計

（三）改良脫莢筒設計

（四）植株排出機構之改良

（五）改良選別與裝袋機構之設計

二、田間試驗

以經本試驗改良之農試型落花生聯合收穫機在產區進行田間試驗、觀察、紀錄各項資料數據並加以分析。

1.臺灣省農業試驗所　研究報告第1513號。

2.本所農機系主任、助理研究及助理（三人）。臺灣省　臺中縣　霧峰鄉。

結果與檢討

一、研製與改良飼株機構[3]：

在上年度中爲解決落花生植株在扶起後紛散，使夾持位置不正確所衍生之諸多問題，曾嚐試以迴轉式供株滾輪强迫飼株，以改善機構之作業性能對紛散植株之整理效果不彰之情形。爲達成强制送株及梳理植株之功用，經力學分析結果指出，以利用二維傾斜角可調式之强制送株鏈爲最理想之設計。該送株機構係安裝在前處理部左、右扶起靴之正上方，並分別向內及向上作二度空間之傾斜，作業時其速度因須與收穫機作業速度同步，故若設收穫機之前進收穫速度爲 V_m 、送株機之速度爲 V_c ，送株機對地傾斜角度爲 θ，植株夾持高度爲H，其對地之水平距離分量爲S ，其關係如圖 1 所示。

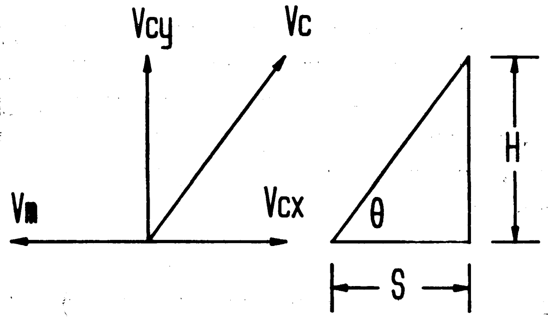

圖1 落花生送株鏈速度分析

爲了使落花生植株在收穫時之夾入完全且無紛散之現象，收穫機前進時送株鏈之爪指由開始接觸植株並向上及向後扶起落花生株，當爪指要離開植株時收穫機應前進到夾入口與植株接觸。亦即收穫機前進 S 所需之時間應與送株鏈向上移動 H 之時間相等。換言之，即送株鏈之水平分速略大或等於收穫機速度。若 N_t、N、P_c 分別代表送株機鏈輪齒數、轉數與鏈條節距， V_{cx} 及 V_{cy} 分別代表送株鏈之水平及垂直分速，則由圖 1 送株鏈之速度圖中可得如下之關係式：

因：

$$V_c = N_t \cdot N \cdot P_c \quad \cdots\cdots (1)$$

$$\frac{S}{V_m} = \frac{H}{V_{cy}} \quad \cdots\cdots (2)$$

$$S = \frac{H \cos\theta}{\sin\theta}$$

$$V_{cy} = V_c \sin\theta$$

則式（2）可簡化爲

$$\frac{V_c}{V_m} = \frac{1}{\cos\theta} \quad \cdots\cdots (3)$$

式（3）等號之右方，其值隨 $\cos\theta$ 而變，但收穫機在作業中因落花生田之畦面變化不大，故送株鏈之對地傾斜角 θ 可視爲一常數。唯收穫機在正常作業時其前進速度亦爲一定值，因此送株鏈之線速或轉速亦恆隨 V_m 以比例常數 $(\cos\theta)^{-1}$ 而變化。而在作業中較理想之傾斜角爲60度，故送株鏈之速度大約爲收穫機前速度之二倍。而送株鏈之設計係採用水稻聯合收穫機所用之排草鏈，其動力由夾持輸送帶之被動輪輸入。經田間試驗結果顯示，其安裝位置對地之淨高嚴重影響作業效果。換言之，以對地相對高度愈小愈理想，這一點嚴格限制送株機動力傳導之選用；爲簡化機構製造作業，初期使用十字叉式萬向接頭，但送株鏈對地高度不符所需。旋經考慮使用球形接頭，亦因裝置後高度仍

不盡理想，幾經選擇後採用內六角球式接頭，經試用結果其作用已符合所求而告定型，其安裝如圖 2 所示。

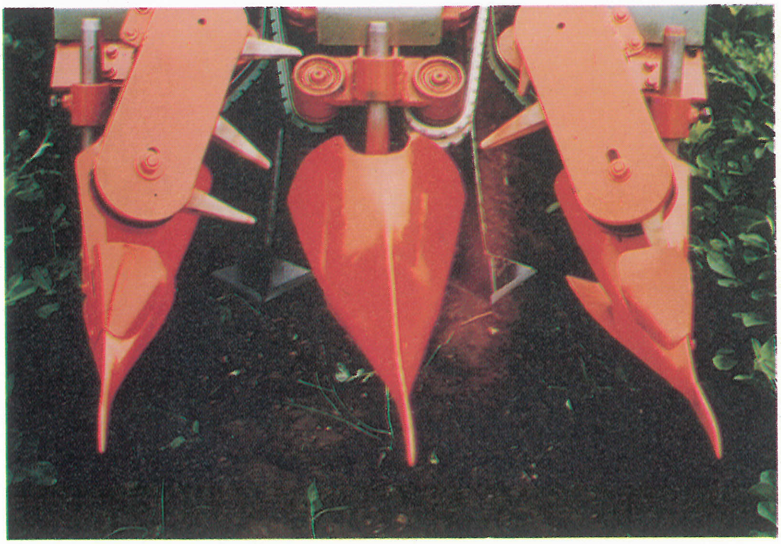

圖2　強制送株鏈

在落花生植株徒長田區，收穫時前處理部之扶起靴雖能完全扶起倒伏之植株，唯扶起靴與強制送株鏈無法將交纏之植株完全分離，此點常爲導致作業中斷淸機之主要原因。爲了突破徒長植株收穫之需，勢需另加必要之輔助分株機構，如圖 3 所示。經試驗結果以原使用之送株滾輪改良後將其迴轉方向改爲向前並移置在强制送株機之前方，其動力由夾株輸送帶動力分頭以傘形齒輪組經萬向接頭、中繼軸傳入滾輪軸，本設計經初步田間試驗觀查結果具有很大之潛力，可解決徒長田區收穫之瓶頸，唯仍需作進一步之試驗以爲驗證。

圖3　輔助分株機構

二、自動位置檢出機構之設計 [5,8]

在本研究中，以機械式電油伺服機構作爲收穫機前處理機構位置自動控制之用，控制機構由伺服放大器、伺服閥、油壓缸及位置檢出器等組成，其流程圖如圖 4：

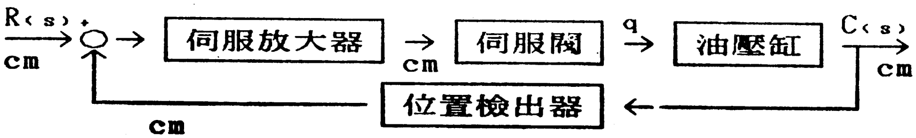

圖4 收穫機前處理部位置伺服控制流程

就整個系統而言，若設伺服放大器及檢出器之增益分別爲 K_a 與 K_f，則伺服迴路之轉移函數方塊圖如下圖 5：

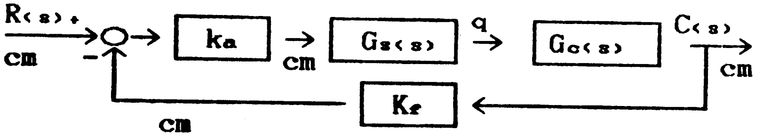

圖5 前處理部位置控制伺服環路方塊圖

經拉氏轉換 (LAPLACE TRANSFORM)，並將各常數值代入可得其轉移函數爲：

$$\frac{C_{(s)}}{R_{(s)}}=\frac{7256}{s^3+143s+7256} \quad \cdots\cdots (4)$$

由式（4），本系統之特性方程式爲：

$$S^2+143S+7256=0$$

其自然頻率 $W_n=85$

系統阻尼 $\xi=0.84$

當輸入爲單位步階時，則輸出

$$C_{(s)}=\frac{7256}{s(s^2+143s+7256)}$$

取反拉氏變化得：

$$c_{(t)}=1-\frac{e^{-\xi\omega nt}}{\sqrt{1-\xi^2}}\sin(\omega_n\sqrt{1-\xi^2}t+\tan^{-1}\frac{\sqrt{1-\xi^2}}{\xi})$$

$$=1-\frac{e^{-71.4t}}{0.54}\sin(45.9t+33) \quad \cdots\cdots (5)$$

本系統之輸出、入可用上式表之，系統在達到置定時間後，其輸出爲零。本位置控制系統經以不同之輸入後，輸出反應如表 1，經迴歸分析結果顯示，其迴歸方式爲：

$$Y=0.065+0.505X \quad \cdots\cdots (6)$$

而其 $R^2=0.9951$，由此可知本系統之反應爲線性且穩定。

表 1. 位置控制系統之輸入與輸出 (MM)

輸 入	1.6	4.7	6.0	8.8	9.1	10.4	10.7	13.5	14.8	15.1	19.5	23.9
輸 出	0.6	2.6	2.9	4.3	4.7	5.0	5.8	7.0	7.4	8.0	10.3	12.5

輸出、入反應之迴歸曲線如圖6：

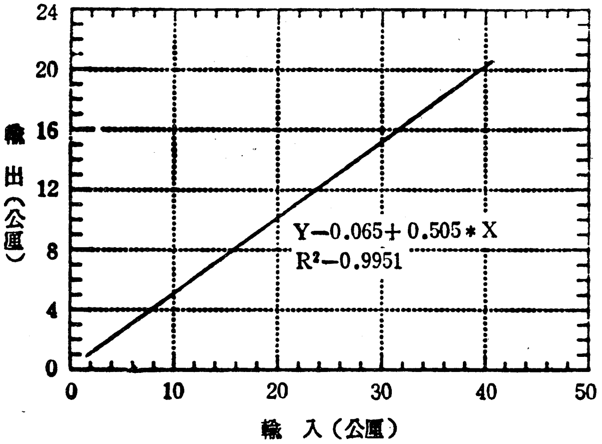

圖6 前處理部位置伺服控制反應之迴歸曲線

本系統之輸出、入雖呈線性之穩定反應，但在安裝上需較大之空間且製造費較高，須以較廉且安裝容易之設計取代之。

三、改良脫莢筒設計 (1,2,4,6,7,9,10,11)

脫莢筒上脫莢環齒之排列原採用雙螺旋之對稱排列方式，其脫莢效率雖已符合作業需求，唯因各列齒間係互相對稱且無重疊，故當脫莢之植株夾持不良而有懸空現象且株長足夠環繞脫莢筒一圈時，在作業中常導致纏筒，並使作業中斷，降低單位時間之有效田間作業能量。為了解決這一瓶頸，除了在脫莢筒入口設法加裝防纏設計外，並將脫莢齒改為三螺旋不對稱之排列方式，並使鄰列相鄰脫莢齒間互有部份重疊，期使各鄰列齒間之空隙去除以減少纏筒之機率。經田間試驗結果顯示，該纏筒之缺點已獲致改善。

以本設計脫莢時植株之長度需達到30公分以上，其脫莢效率方能達到預期之結果，故其使用範圍受到限制。為了克服此一瓶頸，勢需去除目前脫莢筒平行排列所衍生之機構死角，因此嚐試改變脫莢筒為橫向排列，經以試驗裝置初步試驗結果顯示具有正面之改善效果，唯需待組合後進行田間實際作業比較後方能下定論。

四、植株排出機構之改良

為了防止脫莢後植株排出時因受强風吹襲及慣性作用，未自然掉落田間而回繞在輸送帶被動輪上造成異物積堵，使收穫作業中斷；經分析，如果能使排株爪在動力輸入端提早頂出，可收預期之效果。同時若能使植株在進入排出位置與輸送帶脫離，則植株可藉提早頂出之排株爪之排送作用而完全排出，在回程因有强制脫離軌之設計，使植株安全脫離而失去積堵之機會。為了達成前述要求，分別在被動輪上、下方加裝一組圓碟片。該碟片與帶輪支架需盡可能採用小間隙，碟片之外徑需略大於帶輪之有效作用直徑。至於排株爪之提早頂出機構則係利用一組直徑等於鏈輪節徑之厚圓碟片固定在鏈輪上、下方而達成，使排出爪在回程與鏈輪上圓碟接觸時即被强制頂出完成所需之動作，經改良後之機構如圖7所示。

五、改良選別與裝袋機構之設計

在田間試驗觀察中發現，前上集莢帶若仍採用實帶時，則經粗選別後之含土收穫物中之土塊無法先行分離而加大風選負荷。尤其在較潮濕之田間條件下作業時，情況將會更趨惡化。為了改善這一缺失，將實帶改由小節距之柵鏈取代，則莢果中所夾帶之土塊異物在集莢過程中已先行被分離，風選機構之負荷因而獲致改善。

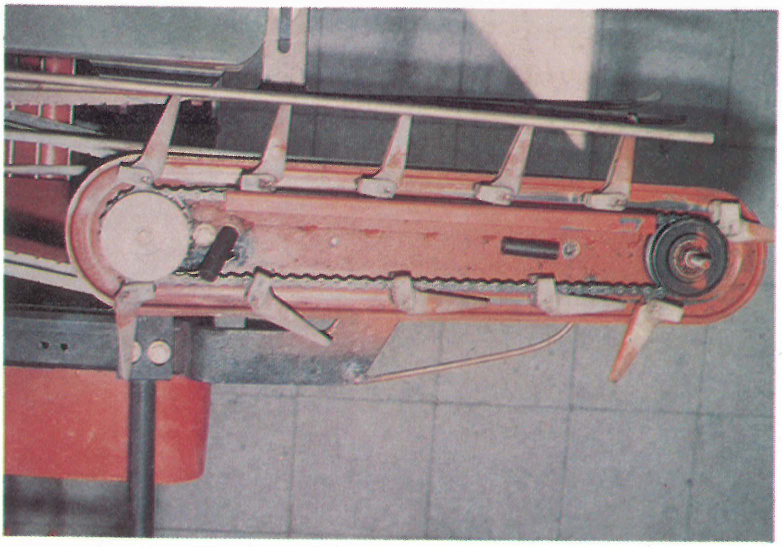

圖 7 排出系統防纏及强制頂出機構

裝袋機之主動輪以大直徑中空之條狀帶輪取代小直徑實心帶輪，可增加裝袋機之驅動能力，避免作業中打滑而夾裂莢果。

討　　論

本收穫機之作業性能經改良後，原有之缺點均已獲致改善。唯需再進行嚴密之田間試驗與重複改良修正，經重複驗證確定後，方能克服目前推廣工作上遭遇使用者持觀望心理之阻礙。同時亟待加强探討之部份機構需繼續研究改良，則農試型落花生聯合收穫機之研究成果方能落實而眞正達成機械化收穫落花生之目標。

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Study on The TARI Peanut Harvester

L. S. Liang[2], J. R. Tsay[3], L. H. Lu[4] S. R. Yen[4] and T. H. Chow[4]

Summary

Employment of forced plant conveyor with auxiliary divider to the front assembly to replace the old one is studied. This device can make the plant holding upright more stably and eliminates the winding problems resulted from abnormal long vines.

With the aid of a strengthen ejector and a break-away device, the discharge of plant after picking becomes certain. The load may be reduced by the modification of the front upper conveyor and the driving shaft of the bagging units. There are no damage and slippage found by using the driving unit. The general capacity of the harvester is then increased to a desired rate.

Key Word: peanut、harvester

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中華農業研究（Jour. Agric. Res. China）39(2)：148～156（1990）

鮮菇超級片型切製機之研製[1]

梁連勝　顏秀榮[2]

摘要：鮮菇超級片型切製機由上滑動刀座總成、下固定刀鈷、下固定刀座及機座組成，切製菇茸時由於滑動刀座受彈簧反彈作用可自動將成品推離刀鈷承座而落入預置容器中；其成品切面平整，經烘乾後外觀不變形，適合生產高品質菇茸片之用，以本機切製菇茸片型產品，平均每小時可切製菇茸1,600個。

關鍵字：鮮菇片、切製機

由於國人生活水準之提昇，消費習慣已由對量的滿足轉變爲質的需求，進而左右生產型態之改變，影響所及農業之生產亦受波及；爲因應消費市場對品質需求之更迭，並提高生產者之收入，本省食用菌類生產者已將其所生產之菇類產品，在應市前加工藉以改變其外觀或改善其品質，其中以鮮菇加工產製超級片型乾菇茸片最具代表性。然而鮮菇超級片型產製之生產過程，目前除以人工手持鮮菇茸再用切刀切製外，有以鋼線切製者或以自動供料滾切者。但前者除作業速度慢，每小時僅能切製約８公斤，產製成本相對提高外，由於其切製厚度無法確定，故烘製後品質參差。而以鋼線切製者因切面不平整，所生產之成品品質不良。後者雖然生產速度較快，但因切製時菇茸未定位，故切製烘乾後之成品商品價值低落而流爲次級品（圖八）。爲克服上述缺點，必需另行開發適用之簡易切製機械以爲因應。

爲了配合生產鮮菇茸片之需要，本所農機研究人員與食用菌研究室合作，進行切製機之相關研究，以克服現有切製方法與設備在進行菇茸片產製時所衍生之缺點，期能生產高品質之菇茸切片，以應高品質消費市場之需，並提高生產者之收益。

材料與方法

一、切製機構之設計與製造

1.設計並研製上滑動刀座總成。

2.設計並研製下固定刀鈷及固定刀座。

3.機座之研製。

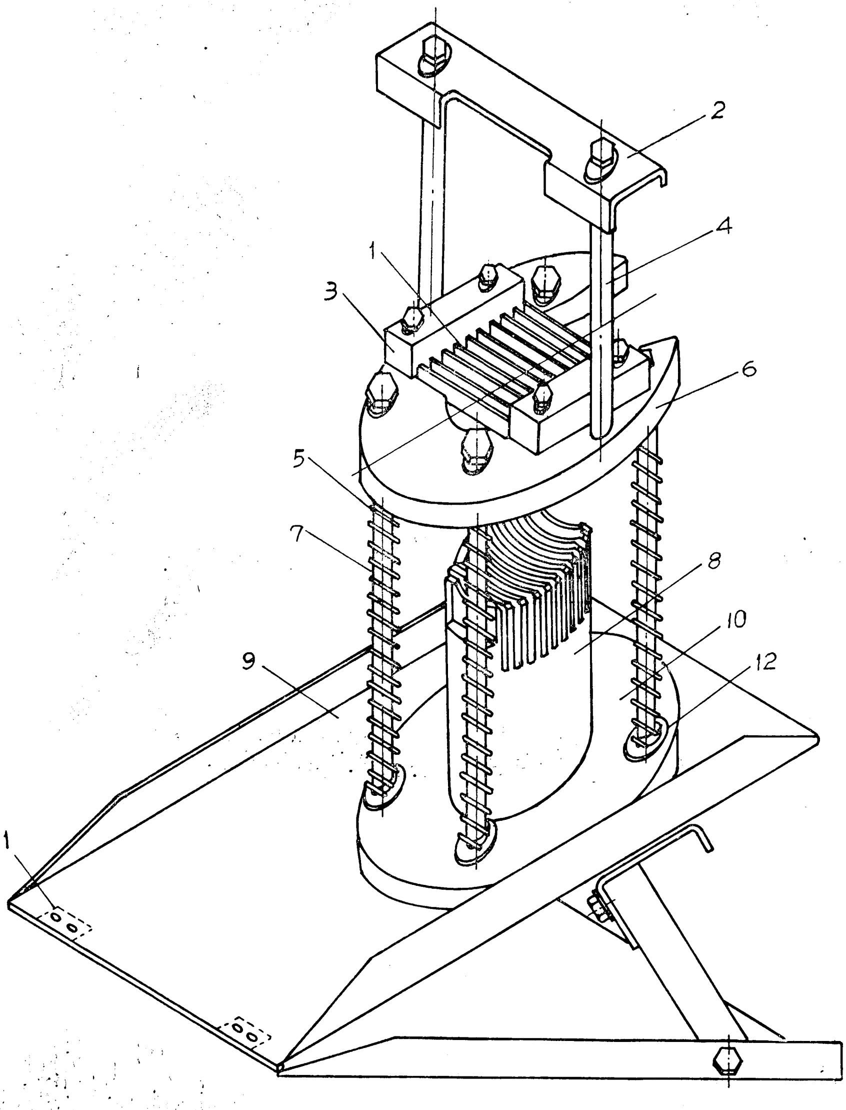
二、鮮菇茸切製試驗與作業能量測定。

結果與檢討

本機以質輕之鋁材加工製造，其組成包括一組上滑動刀座總成、下固定刀鈷、下固定刀座、導套

1.臺灣省農業試驗所　研究報告第1514號。

2.本所農機系主任及助理。臺灣省　臺中縣　霧峰鄉。



圖一

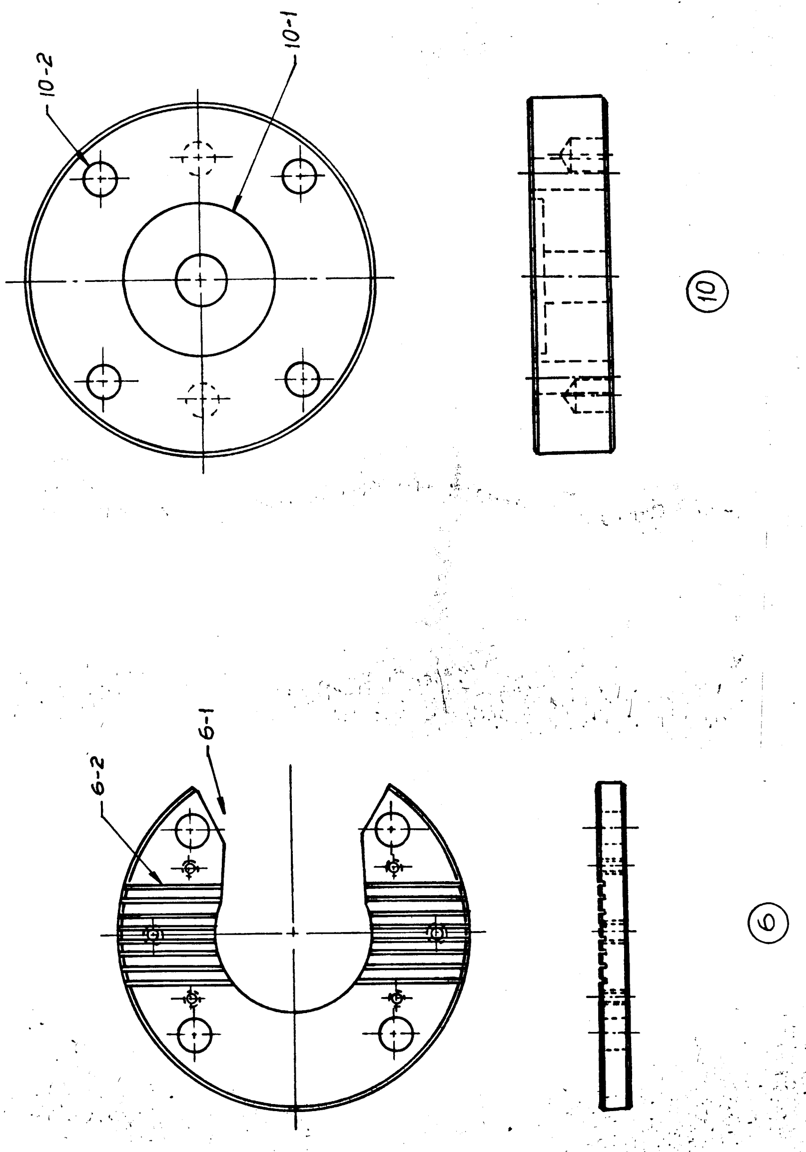
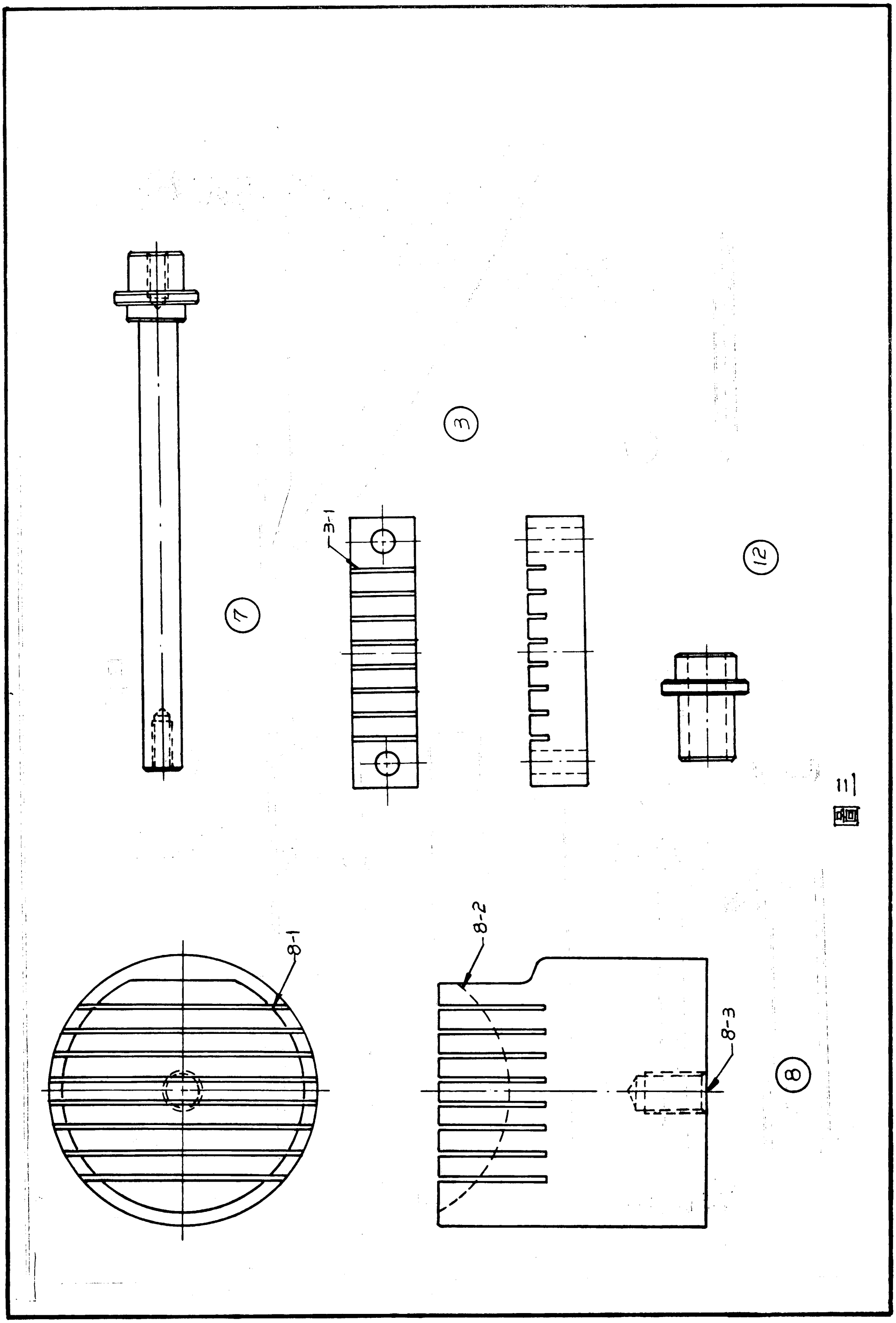
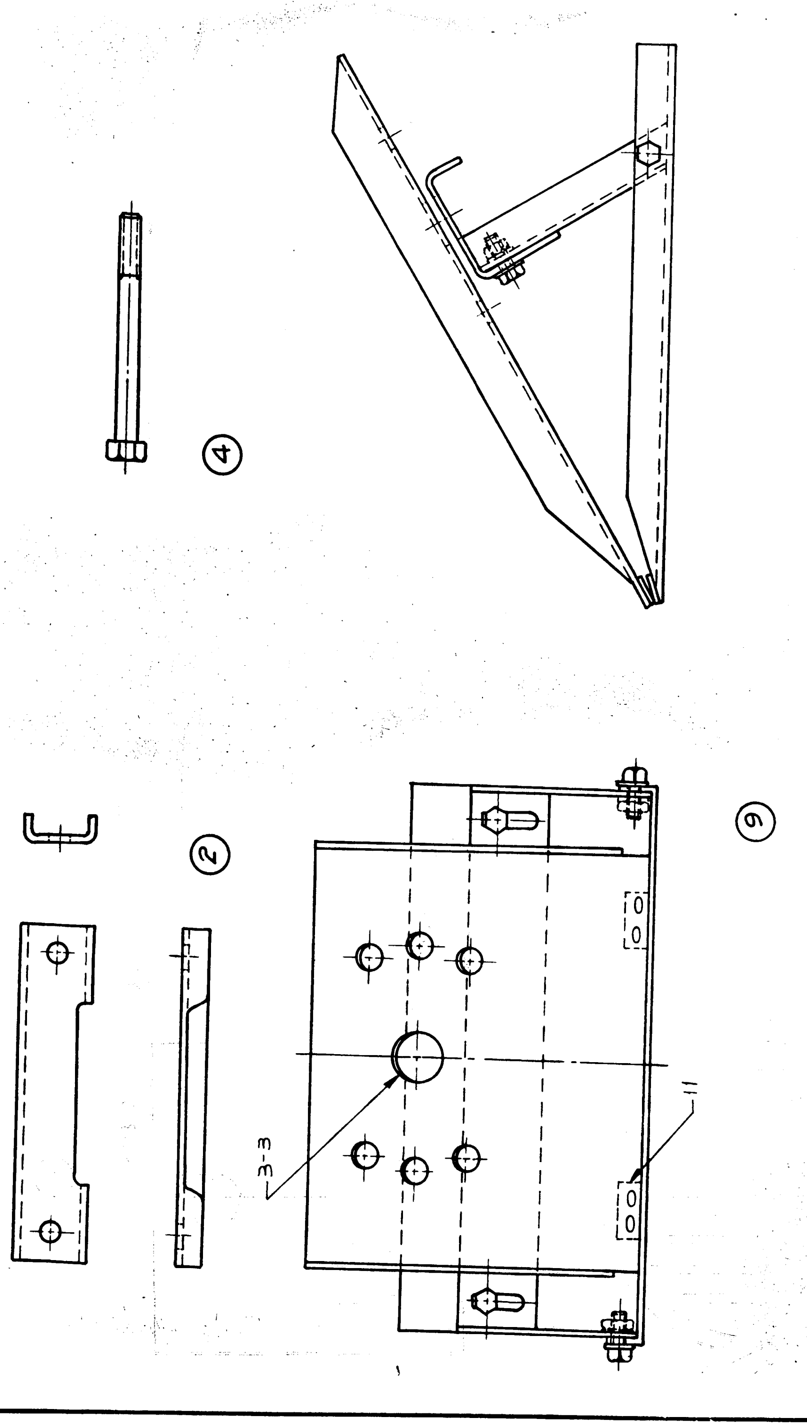


圖 11



圖三



圖四

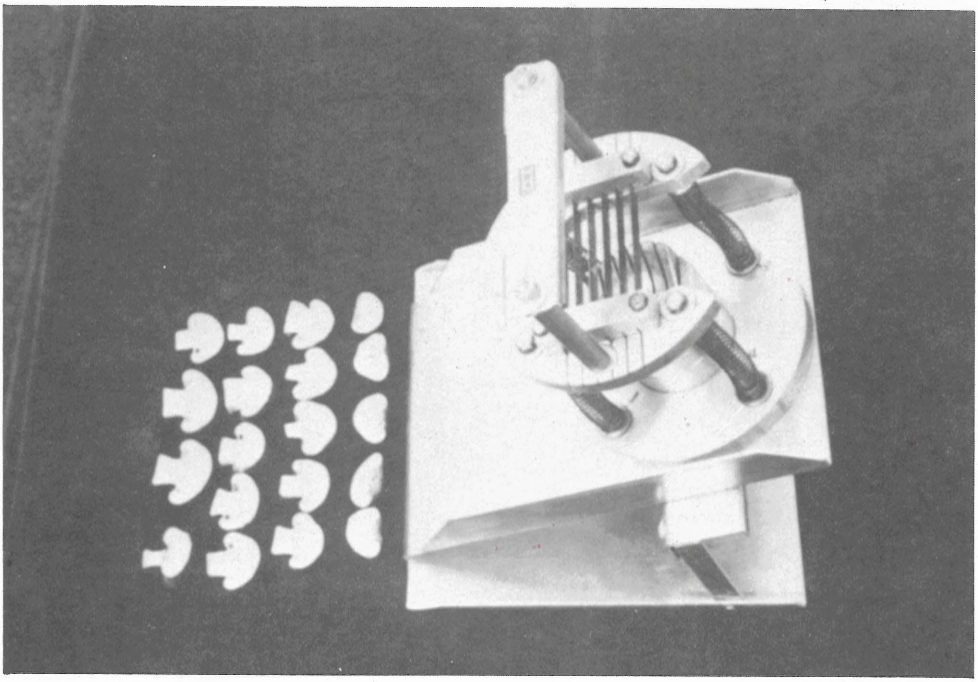


圖5. 鮮菇超級片型切製機

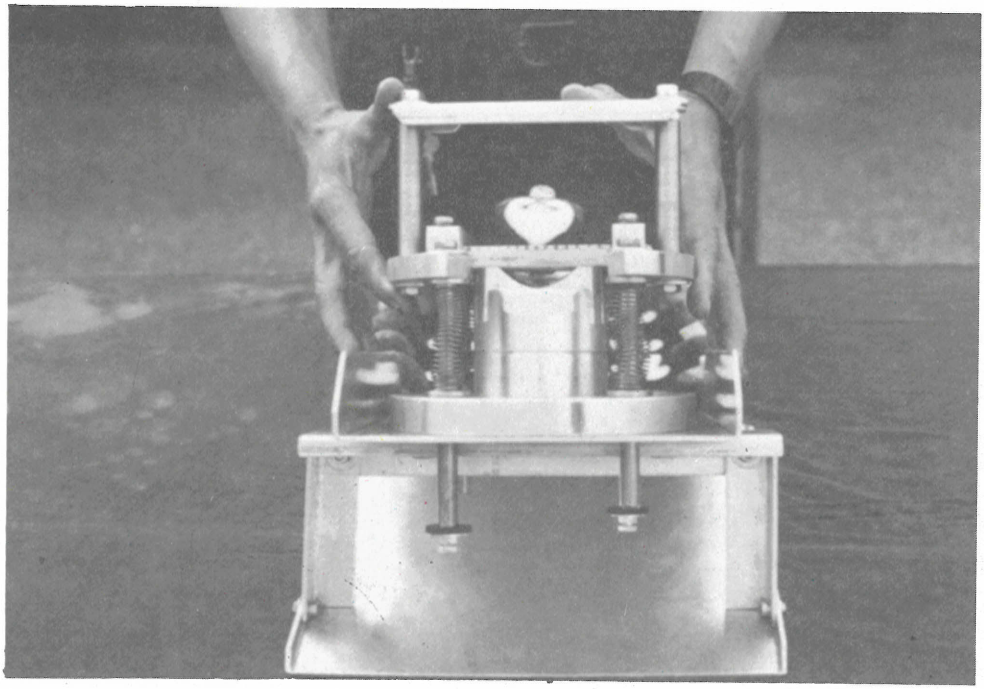


圖6. 菇茸片之推離

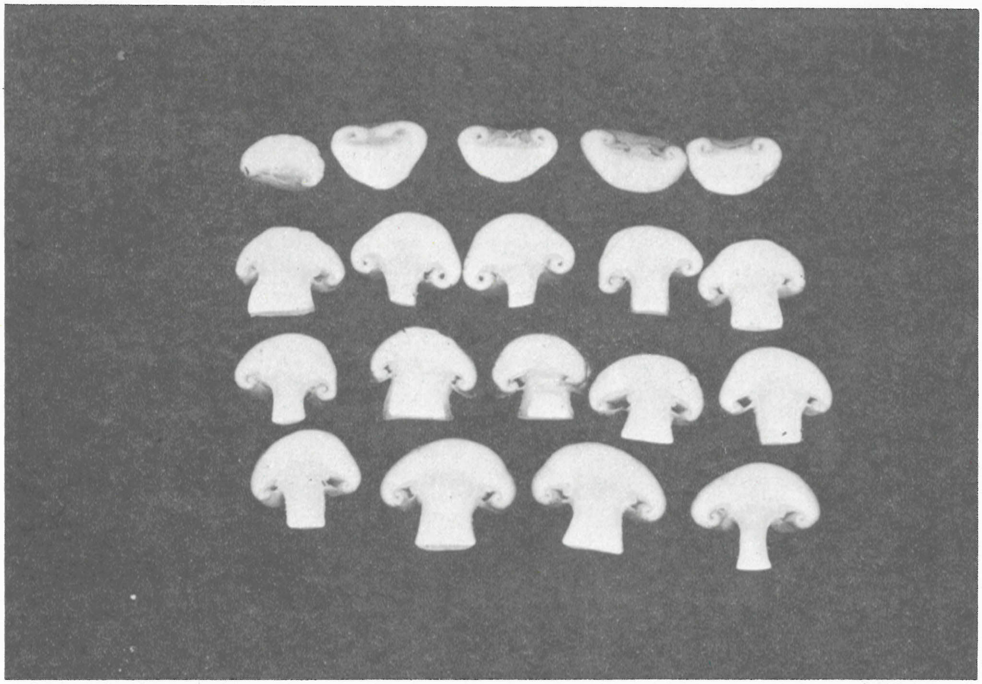


圖7. 切製之鮮菇茸片

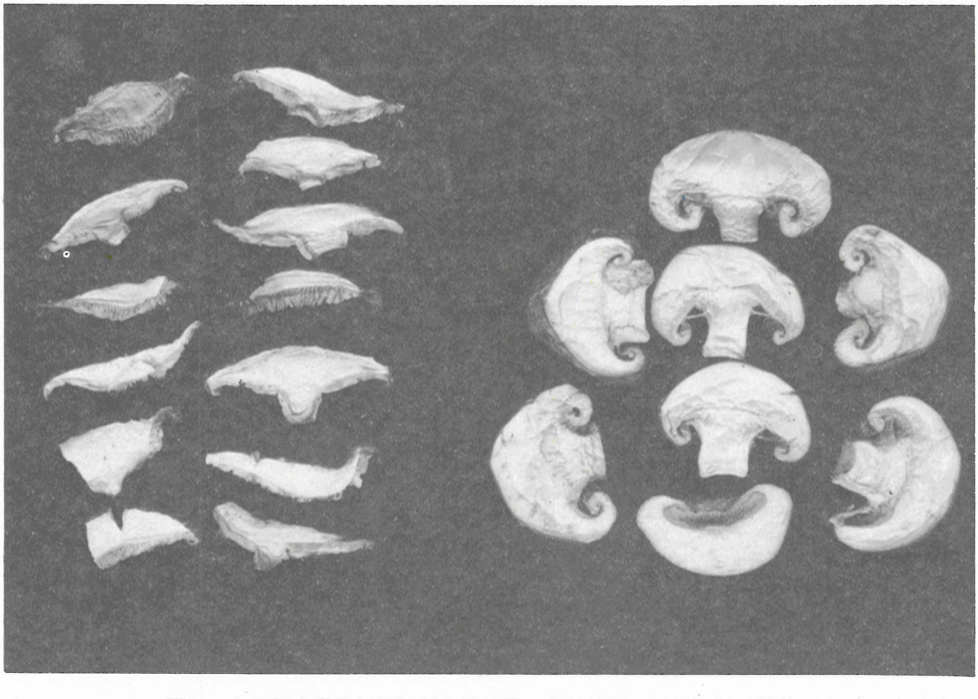


圖8. 左爲用自動滾切機切製之乾菇茸片右爲使用本創作切製之菇茸片

及可調式不銹鋼機座等機構。上滑動刀座總成由施力手把（圖一之2）、手把固定螺桿（圖一之4）、切刀固定夾（圖一之3）、切刀組（圖一之1）及附刀槽之滑動刀座（圖一之6）、一組滑動導桿（圖一之7）與回復彈簧（圖一之5）組成。下固定刀鉆（圖一之8）之承座（圖三之8－2）車製成蕈傘圓弧形，承座上並銑製刀槽（圖三之8－1），然後固定在下固定刀座（圖一之10）上，並可藉微調孔（圖四之9、8－3）進行上、下刀座間相對位置之微調整。下固定刀座上裝配一組導套，以供滑動導桿在切製過程中沿導套內管上下滑動，滑動桿與導套爲滑配，以免機構在作業中產生干涉。下固定刀座固定在可配合人體工學在作業中進行調整傾斜角度之傾斜機座（圖一之9、11），全機之組成立體圖如圖一及五所示，其零件如圖二、三及四所繪者。

爲了方便鮮菇茸供料，上滑動刀座設計成凹形缺口。切製時操作者以左手持菇茸由凹形缺口放置在下刀鉆之蕈傘圓弧形承座內，完成自然定位之作用。接著右手按在施力把手上持續施力，上滑動刀座總成沿滑動導桿向下移，切刀接觸菇傘後繼續下滑並切過蕈傘，切入下固定刀鉆之刀槽中，完成切製過程。當施力移去後，因回復彈簧受壓縮後反彈，使上滑動刀座總成反向上移復位，等待下一作業行程。由於上滑動刀座上移作用將已切製之菇茸片向上推離下刀鉆承座（圖六），並沿機座傾斜面向下落入預置容器中，完成一完全之切製行程。傾斜機座以鉸鏈相連，傾斜面可因作業者人體工學及菇茸物理性質之需要，於作業中適時予以調整。

經室內實際切製新鮮香菇茸（圖七），平均每小時可切菇茸片約35公斤，所得之片型切面平整且厚度一致，經烘乾後品質優異符合高品質之標準（如圖八）。本機之單位時間作業能量約爲人工之4倍，所生產之片型菇茸品質遠優於以其他方法切製者，同時生產成本亦較低廉。

討　論

以本機切製菇茸片時，最好以現採之鮮菇茸爲原料，否則因菇茸失水致切製較費力。切製前應將切製機以固定夾固定在工作桌上，以便穩定作業。由於本設計爲一簡易型切製設備，可供切製其他片型食品之用。若要提高單位時間作業能量，可朝自動供料設計之配合進行研究。

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Study on The Fresh Mushroom Chopper[1]

L. S. Liang[2], S. R. Yen[3]

Summary

The fresh mushroom chopper consists of a upper sliding assembly and a bottom seat with frame. During the operation, the chopped mushroom is pushed off from the bottom seat as a result of the affect of the reset spring and then goes down to the receiver. The cut surface of the product is smooth and flat. The whole slice will maintain its original shape after the drying process. The apparatus is good for producing the baby mushroom slices of high quality. The average working speed reaches about 1600 pieces. per hour.

Key Word: mushroom、chopper

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A Study on Mathematical Models for Predicting Water Activity in Multicomponent Foods

Chia-Chung Chen[2]

Abstract : A model to predict water activity (equilibrium relative humidity/100) in multicomponent food mixtures is developed. It is based on balancing masses of water and dry matter and assumes that no interactions affecting water activity of the ingredients occur during mixing. Explicit solutions are presented for the linear and Smith forms of the isotherm equations. A numerical procedure is used to calculate the water activity for nonlinear isotherm equations. An example using data fro m the literature illustrates very good fittings by using appropriate isotherm equation for calculating of water activity of the mixture.

Introduction

A frequent operation in the development of food products is the mixing of different ingredients to produce a composite food. When these ingredients are mixed and sealed perfectly, they will reach a final equilibrium state by a change in moisture. The driving force is due to the difference in the vapor pressures of the ingredients.

Because of the importance of water activity (equilibrium relative humidity/100) on the storage properties of foods, such as hardness, storage period, and crispness, it is often necessary to know the final water activity (A_w) of the mixture. Several equations that predict the water activity of the final equilibrium state of the composite food have been proposed. Salwin and Slawson (1959) assumed the sorption isotherms of foods exhibited a linear relationship between A_w and moisture content. They gave an equation for predicting water activity based on the initial A_w value, weights, and parameters of the linear line for each ingredient. Unfortunately, the linear relation was not valid in the low and high ranges of water activity.

Lang and Steinberg (1980) attempted to show the validity for the hypothesis that at a given A_w the moisture content of a mixture was equal to a weighted average of the moisture content of each component at that A_w. They concluded that each compon-

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ent absorbed water independently of the others. Similar research by Iglesias et al. (1980) found that the interactions between components definitely altered the individual sorption properties, leading to significant differences between predicted and measured values.

Using the equation presented by Smith (1947) instead of the linearized isotherm, Lang and Steinberg (1981) proposed a new equation to predict the final water activity by knowing the weight and parameters of the Smith equation for each component and the moisture content of mixture. The applicable range of A_w for this equation is from 0.30 to 0.95.

The linear and Smith isotherm sorption equations are only valid in a limited range and have only been fit for particular food products. Therefore, a general model for predicting Aw with the best "fitting-agreement" equation for each ingredient over the applicable range would be useful.

Model Development

The assumption for this model is that there is no moisture loss or gain in the system during the mixing process. To ensure the validity of the A_w prediicton, the model also requires no direct interactions between the ingredients of the mixture.

From the concept of a mass balance, the total quantity of water within the mixture is equal to the sum of the water that exists in each ingredient and can be expressed as

$$W_t * M_t = \sum_{i=1}^{n} W_i * M_i \quad \cdots\cdots (1)$$

where: M_i = moisture content of ingredient i, decimal dry basis
M_t = moisture content of mixture, decimal dry basis
W_i = dry matter of ingredient i, g
W_t = total dry matter, g
n = number of ingredients in mixture

Assuming no moisture loss during the mixing process, then,

$$W_t * M_t = \sum_{i=1}^{n} W_i * M_i(\text{initial stage}) = \sum_{i=1}^{n} W_i * M_i(\text{final stage}) \quad \cdots\cdots (2)$$

Under constant temperature, the moisture content of foods can be expressed as a function of water activity.

$$M = f(A_w) \quad \cdots\cdots (3)$$

Therefore,

$$W_t * M_t = \sum_{i=1}^{n} W_i * f_i(A_{wi}) = \sum_{i=1}^{n} W_i * f_i(A_{weq}) \quad \cdots\cdots (4)$$

where: A_{wi} = initial A_w of ingredient i, decimal
A_{weq} = equilibrium A_w of mixture, decimal
f_i = isotherm function for ingredient i

Any sorption equation can be substituted into Eq. (4) to solve the mixing problem. Since each food ingredient has its own characteristic "best fit" equation for its applicable range of A_w, Eq(4) can serve as the universal equation for the mixing operation.

The linear equation and Smith equation have a linear form for moisture content. Eq (4) can be further simplified in these cases.

Linear Isotherm Equation

$$M=b*A_w+c \quad (5)$$

Substituting into Eq (4) yields

$$W_t*M_t=\sum_{i=1}^{n} W_i*f(A_{wi})=\sum_{i=1}^{n} W_i*(b_i*A_{wi}+c_i) \quad (6)$$

$$W_t*M_t=\sum_{i=1}^{n} W_i*f(A_{weq})=\sum_{i=1}^{n} W_i*(b_i*A_{weq}+c_i) \quad (7)$$

Combining Eq (6) and Eq (7) and solving for A_{weq} yields

$$A_{weq}=\frac{\sum_{i=1}^{n} W_i*b_i*A_{wi}}{\sum_{i=1}^{n} W_i*b_i} \quad (8)$$

Eq (8) is the model developed by Salwin and Slawson (1959). When the moisture content of the mixture is known, Eqs. (6) and (8) can be combined into the form.

$$A_{weq}=\frac{W_t*M_t-\sum_{i=1}^{n} W_i*c_i}{\sum_{i=1}^{n} W_i*b_i} \quad (9)$$

Smith Isotherm Equations

In the Smith equation, M and In $(1-A_w)$ have a linear relation:

$$M=a+b*\ln(1-A_w) \quad (10)$$

Substituting Eq (10) into (4) yields

$$W_t*M_t=\sum_{i=1}^{n} W_i*f(A_{wi})=\sum_{i=1}^{n} W_i*(a_i+b_i*\ln(1-A_{wi})) \quad (11)$$

$$W_t*M_t=\sum_{i=1}^{n} W_i*f(A_{weq})=\sum_{i=1}^{n} W_i*(a_i+b_i*\ln(1-A_{weq})) \quad (12)$$

Therefore,

$$\ln(1-A_{weq})=\frac{\sum_{i=1}^{n} W_i*b_i*\ln(1-A_i)}{\sum_{i=1}^{n} W_i*b_i} \quad (13)$$

When the moisture content of the mixture is known, combining Eqs (11) and (13) results in:

$$\ln(1-A_{weq}) = \frac{W_t * M_t - \sum_{i=1}^{n} W_i * a_i}{\sum_{i=1}^{n} W_i * b_i} \quad \cdots\cdots (14)$$

This is the equation proposed by Lang and Steinberg (1981).

Nonlinear Isotherm Equations

Several common sorption equations have nonlinear forms. These include equations presented by Henderson (1952), Chung and Pfost (1967), Halsey (1947), Halsey (1948), Oswin (1946), and Brunauer et al. (1938).

Because no linear relation exists between the moisture content and A_w (or the transformed A_w), these equations cannot be simplified as can the linear and Smith equations. Therefore, an explicit expression for the A_w of the mixture cannot be found. However, the solution can be found by numerical methods. A simple iterative scheme can provide a convenient and rapid way of predicting the final A_w value for the mixture.

There are three methods to obtain the roots of a nonlinear equation. Due to the curvature of the sorption isotherm, divergence could occur for the Newton and secant methods in the inflection region. Also, the Newton method involves a complex form of the first derivative for the sorption equation. The bisection method provides a good method to obtain the solution (Atkinson, 1985).

Application of Model

The mixing of dried egg albumen and soy protein was selected as the example to predict the water activity of the mixture. These data are adopted from Bone (1987).

The nonlinear isotherm equation chosen to fit the data is the one presentede by Oswin (1946). The equation is,

$$M = b * \left(\frac{A_w}{1-A_w}\right)^{c} \quad \cdots\cdots (15)$$

where: b and c are product parameters.

For egg albumen, the Oswin equation becomes,

$$M = 11.711 \left(\frac{A_w}{1-A_w}\right)^{0.60496} \quad \cdots\cdots (16)$$

The linear sorption equation for this product is,

$$M = -16.063 + 56.276 * A_w \quad \cdots\cdots (17)$$

For soy protein, the Oswin equation becomes,

$$M = 10.010 \left(\frac{A_w}{1-A_w}\right)^{0.53050} \quad \cdots\cdots (18)$$

The linear equation is,

$$M = -10.105 + 41.896 * A_w \quad \cdots\cdots (19)$$

The isotherm data at 25°C for both ingredients and the Oswin equations (16 and 18) fit to the data are plotted in Figure 1. The equations closely fit the data.

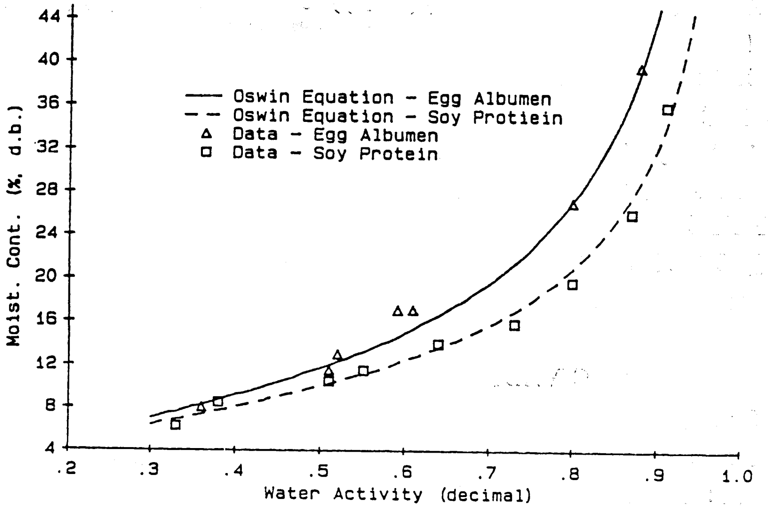

Figure 1. Adsorption isotherms at 25°C, for dried egg albumen and soy protein (data from Bone, 1987).

A 50 : 50 blend of dried egg albumen and soy protein was used to compare the validity of the prediction for the mixing model.

Combining Eq. (4) and the two isotherm equations, the predicted isotherm relation for the mixture for the linear equation is,

$$M_t = -13.084 + 49.086 * A_w \quad \cdots\cdots (20)$$

and for the Oswin equation is,

$$M_t = 5.0051 * \left(\frac{A_w}{1-A_w}\right)^{0.53050} + 5.8555 * \left(\frac{A_w}{1-A_w}\right)^{0.60496} \cdots\cdots (21)$$

The A_w value for each M_t can be solved by Eq (20) or (21). A program written in BASIC that solved Eq (21), a nonlinear equation, is shown in the Figure 2. Other nonlinear equations can also be solved with this program. For mixing conditions, the user needs ony to substitute the new equation in the program at line 30.

The actual A_w values and the predicted values from the two sorption equations (20 and 21) are shown in Fig. 3. The Oswin equation provides good results, especially for an A_w of 0.6 to 0.75 which is the range where development of fungi starts. Large deviations are found for the results of the linear equation. This prediction would give incorrect information about safe storage of food products. For example, the actualaA$_w$ for the mixture of 18% m. c. is nearly 0.7, a critical level for fungi development. However, the linear equation predicts a value for A_w of 0.62 which appears to be relatively safe. These results show the importantance of using an appropriately shaped isotherm equation when evaluating mixing problems.

```
10 REM: SOLVE NONLINEAR EQUATION BY BISECTION METHOD
20 INPUT "MT=?"; MT
30 DEF FNE(X)=MT-5.0051*(X/(1-X))^0.53050-5.8555*(X/(1-X))^0.60496
40 REM
50 A=0.01 : B=0.99 : C=0.5
55 D=B-C
60 IF ABS (D)<1.0E-5 GOTO 150
70 PB=FNF (B) : PC=FNF (C)
80 J=PB*PC
90 IF J>0 GOTO 110
100 A=C : GOTO 130
110 B=C
120 REM: UPDATA C VALUE
130 C=(A+B)/2
140 GOTO 55
150 PRINT: PRINT "AW=" ; C
209 END
```

Figure 2. BASIC program to solve a nonlinear equation by the bisection method-example equation defined in line 30.

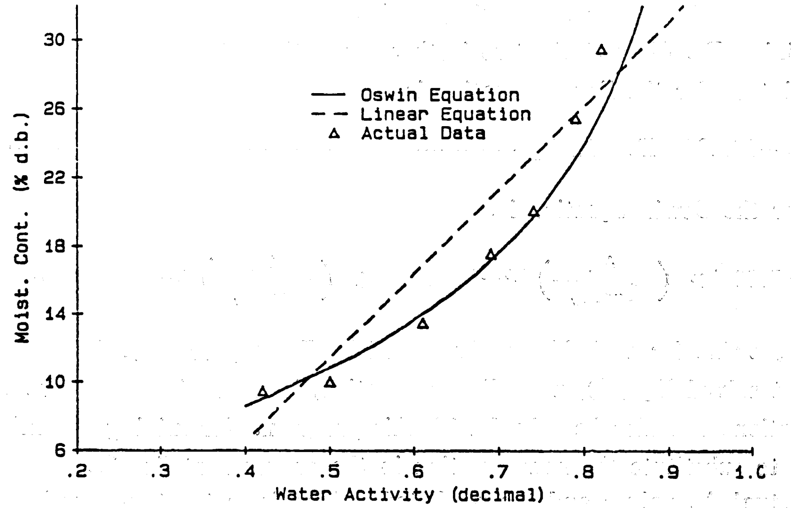

Figure 3. Predicted and actual isotherms at 25°C for 50 : 50 mix of egg albumen and soy protein (data from Bone, 1987).

Summary and Conclusions

The relationship of water activity for multicomponent foods to the components making up the mixture is developed using a mass balance principle. Because of the limited A_w range for the application of the linear and Smith isotherm equations, nonlinear sorption equations provide a better fit for sorption data. A numerical procedure

using the bisection method to solve nonlinear equation isotherm was developed. An example mixing problem showed that a nonlinear isotherm equation provided better prediction of water activity than a linear eqvation.

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多成份食品水活性之預測模式

陳 加 忠[2]

摘　要

食品水活性的性質在混合、貯存、運輸等加工作業上十分之重要。此研究之目的即在於推導與驗證由多種成份混合製成食品的水活性預測模式。其應用之假設條件為食品乾物質與所含水份的總質量不變，且在混合過程中無化學反應發生。利用等溫水份線的直線公式和史密斯公式，雖然可以直接求得預測值，但誤差偏大。利用非線性公式推衍所得的混合模式可以以數值方法求得預測值，其驗證結果則十分精確。

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